WEAPONS AT SEA

ON 4 MAY 1982, SHEFFIELD – a British destroyer serving in the South Atlantic – suffered a direct hit. Sometime in the late afternoon, her radar system had detected an impending enemy attack. Her captain barely had time to shout, 'Take cover' as the missile – a deadly AM39 Exocet – hit the ship, ripping a hole in her side.

The effect of the impact was overwhelming. Twenty crew members were killed instantly, and the resulting explosion cut out all lighting and communications systems. Within 20 seconds, there was a roaring mass of flames and clouds of black smoke. Within minutes, HMS *Sheffield* was devastated.

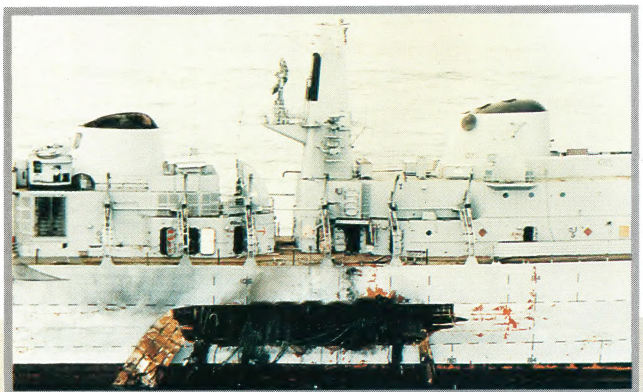
Sea Skimmers

The loss of *Sheffield* marked a turning-point in the history of naval warfare; the use of Exocet heralded the beginning of a new age in sea weaponry.

Before 1982, anti-ship attack consisted of high-flying missiles which were tracked by radar and shot down like an aeroplane. These have largely been superseded by a new breed of missiles called Sea Skimmers. Guided by radar, their advantages are enormous. Instead of approaching the target from overhead, the missile flies close to the sea surface to avoid detection by radar. Known as a 'fire and forget' missile – once launched, the operator can forget about it – it will find its own way to its target.

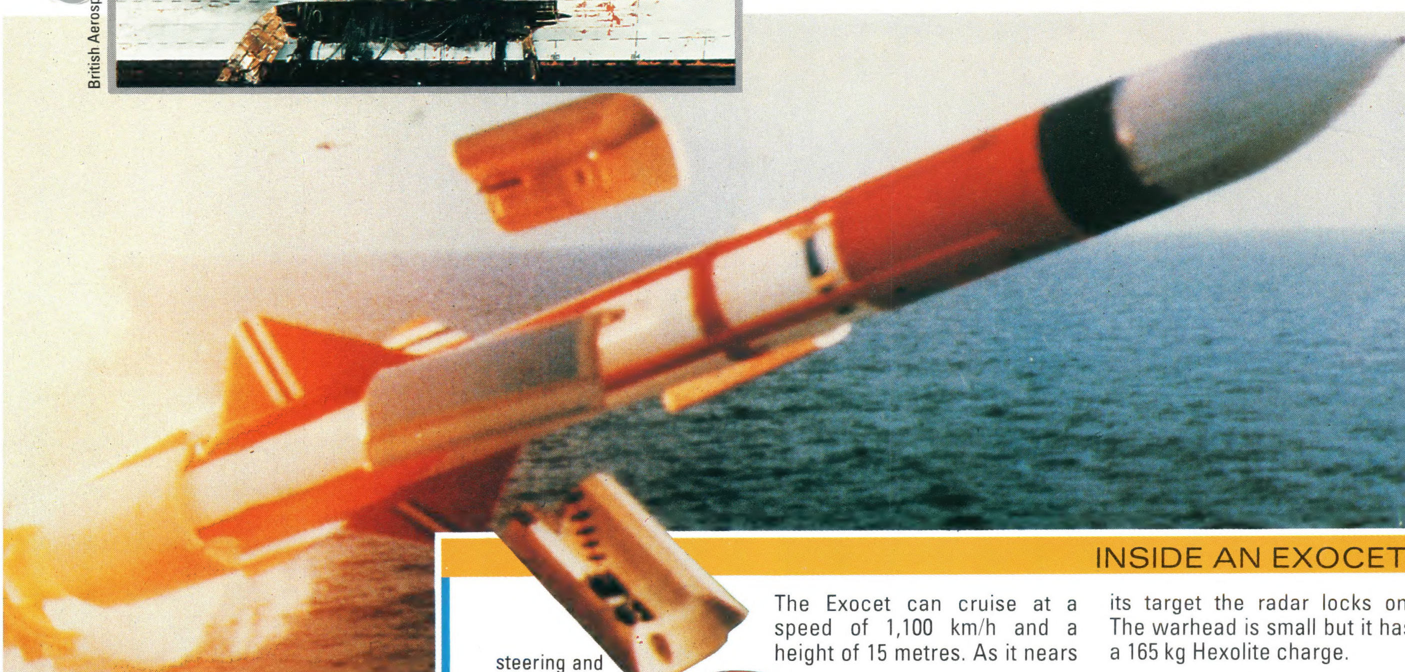
Exocet measures 5.2 metres in

- THE DEADLY EXOCET
- FLOATING FORTRESSES
- NUCLEAR SUBMARINES



British Aerospa

***Sea-skimming** missiles pose a serious threat in sea warfare, as was illustrated by the damage caused to HMS Devonshire during a deliberate controlled firing exercise.*

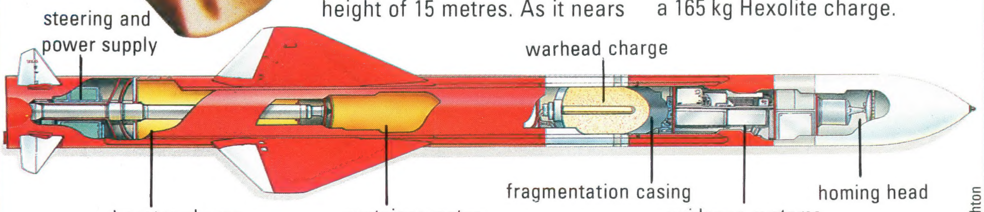


Frank Spooner Pictures

***An MM40** Exocet roars into life. The pieces flying off are spacers, which guide and protect the missile during its journey through the launcher. After launching, they are no longer needed and are discarded automatically.*

INSIDE AN EXOCET

The Exocet can cruise at a speed of 1,100 km/h and a height of 15 metres. As it nears its target the radar locks on. The warhead is small but it has a 165 kg Hexolite charge.

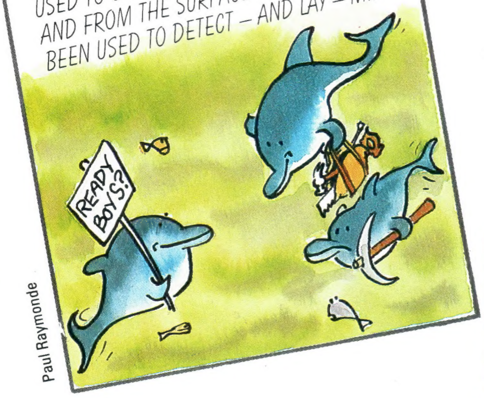


John Houghton

Just amazing!

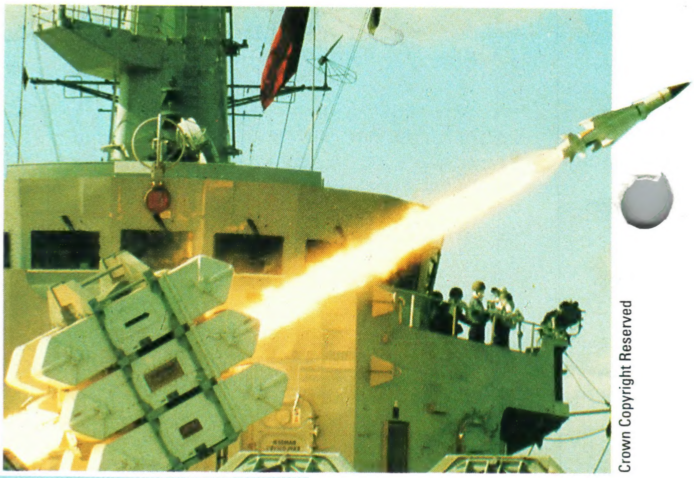
CHEAP SEA DIVER

THE AMERICANS HAVE FOUND AN INEXPENSIVE – AND VERY EFFICIENT – UNDERSEA DIVER. DOLPHINS HAVE BEEN USED TO CARRY MESSAGES AND TOOLS TO AND FROM THE SURFACE. THEY HAVE EVEN BEEN USED TO DETECT – AND LAY – MINES.



Paul Raymonde

***Seawolf** is the latest generation of Royal Navy air defence missile. Entirely automatic and self-guiding, it can set itself to explode, either when it hits the target, or when it is close to the target.*



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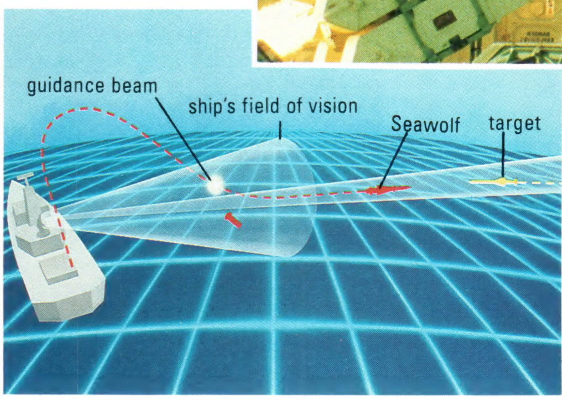


British Aerospace

***The highly** accurate guidance method used by Seawolf is known as Command to Line of Sight (CLOS). Electronic equipment on the carrier ship tracks the target. Seawolf is then steered towards it by a beam of guidance commands.*

length, 350 mm in diameter, and has a one metre wing span. Before launching, its computerized guidance system is provided with information, such as the bearing and range of the target ship and the height it must fly above water. After launching, the missile's rocket motor takes it to a speed of Mach 0.93 (1,140 km/h) – almost the speed of sound – as it dives to wave-top height, and then skims over the sea's surface, towards the enemy ship.

When the Exocet is within 14 km of its target, it automatically switches on its radar scanner. The scanner detects the target, works out how far the missile is off course (the target may have moved in the two or three minutes since the missile was launched) and then points it in the right direction for a direct hit. If it doesn't make a direct hit, a fuse will automatically set the warhead off close enough to cause major damage to the target ship.

The firepower of Exocet shown during the Falklands conflict in 1982 led to many countries producing their own, more sophisticated versions. Typical examples are the Israeli 'Gabriel' , the Italian 'Otomat' (which uses a rocket booster to launch it) and the British Sea Skua – one of the few sea-skimmers to be launched from a helicopter.

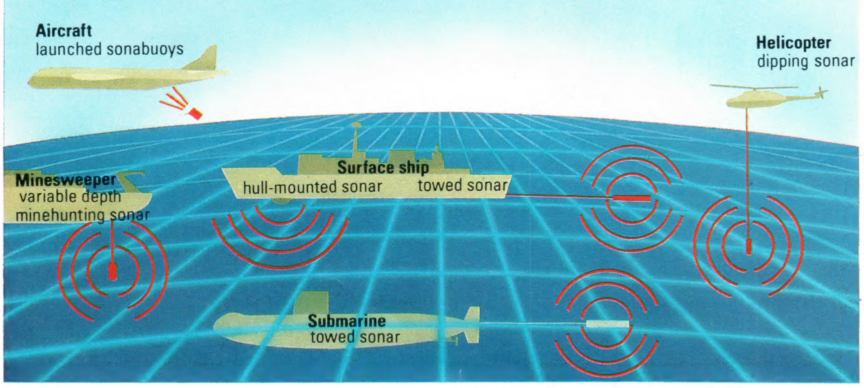
Probably the most formidable of all missiles, however, is the Russian SS-N-3 Shaddock – whose maximum range of 750 km dwarfs that of its European counterparts, with their range of 50–70 km.

SONAR GUIDE

TRH Pictures

Sonar operators use advanced display techniques to monitor enemy positions. Whereas radar uses radio waves, sonar uses high frequency sound waves. Both are vital in modern sea warfare and defence.

Sonar is particularly effective underwater, where it is used to detect enemy shipping, torpedoes and mines. Sonar can be equally effective when controlled by aircraft or sea-going vessels (even fishing vessels carry sonar to detect shoals of fish). Five methods of using sonar are shown below.



Stan North

Missile attack!

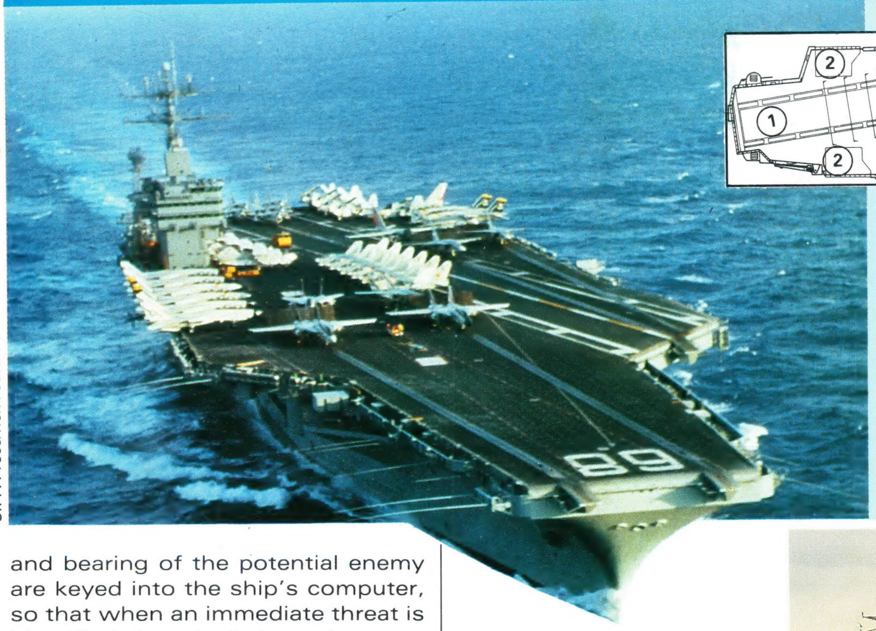
As soon as an attack is detected, it is essential to take avoiding action. A ship cannot be moved quickly enough to avoid being hit, so the fast-approaching missile has to be 'put off the scent' – by electronic counter-measures, which would seek to upset its guidance – or destroyed.

There are two options for counter attack: gun or missile systems. The Americans have opted for a gun system, typified by the 'Phalanx' system, which uses radar to direct a gun towards the missile. Its 20 mm shells are poured out at 3,000 rounds per minute, practically guaranteeing a hit every time.

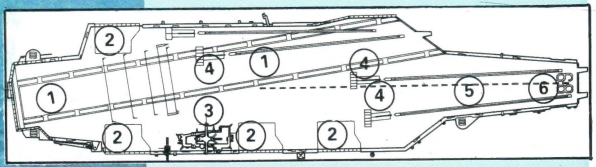
Seawolf

By contrast, the British Royal Navy has opted for anti-missile missiles, of which the most impressive is Seawolf. The main virtue of this defence missile is its fast reaction time. Within thousandths of a second of detection by the ship's search radar, 'friend or foe' interrogation of the target takes place. At the same time, the range, speed

FLOATING FORTRESS



SIPA Press/Rex Features



The enormous Nimitz class carriers are powered by two nuclear reactors, which provide speeds of up to 30 knots (55.5 km/h). They can remain operational for 13 years before refuelling, and are able to launch their complement of aircraft at the rate of three per minute. Key to flight deck (inset): **1** landing guide-lines **2** aircraft elevators **3** radar/control tower **4** jet efflux deflectors **5** launching catapults **6** identification mark.

and bearing of the potential enemy are keyed into the ship's computer, so that when an immediate threat is identified, the missile is ready to go.

Powered by solid-fuel motors (it has a boost stage for even faster launching), the missile is steered towards its target by guidance commands transmitted in a narrow beam to aerials on the missile. Seawolf will cope with a missile flying at speeds above Mach 2 (2,450 km/h) – twice the speed of sound – and can actually split a shell in half when in flight.

Yarrow Shipbuilders

***HMS Cornwall**, a Type 22 frigate, was commissioned to provide an all round defence capability for the Royal Navy. Designed for anti-submarine warfare, it is fitted with torpedo tubes, and can carry both Harpoon and Seawolf missiles.*

Aircraft carriers

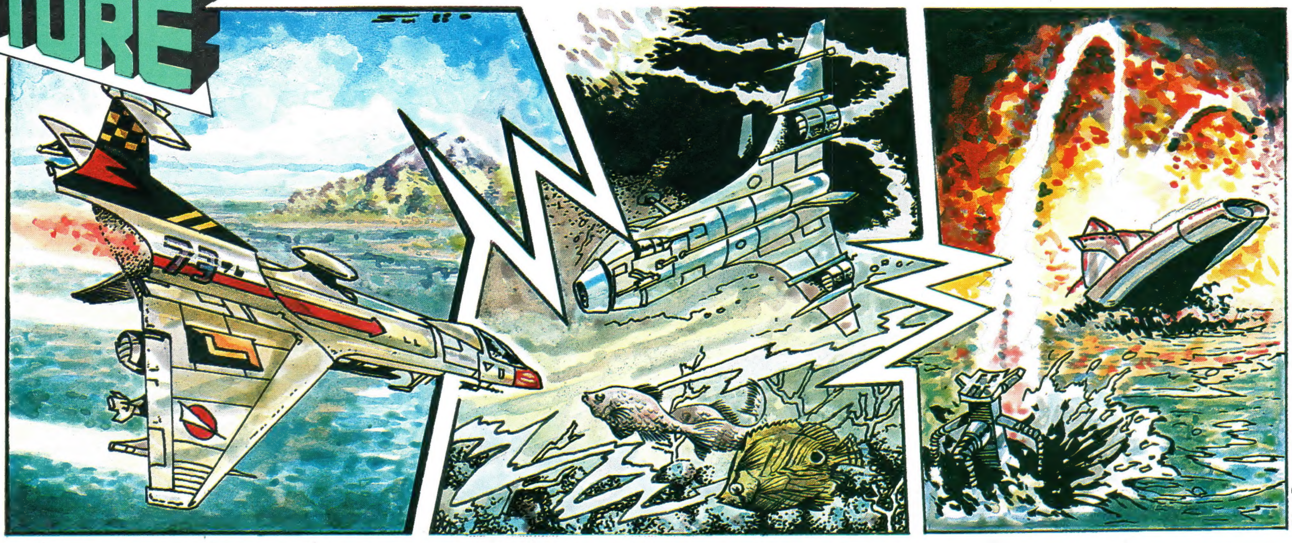
The world's largest and most sophisticated aircraft carriers are the USS 'Nimitz' class carriers. Each ship weighs over 90,000 tonnes, the largest – *Theodore Roosevelt* – being 97,000 tonnes. They are 333 metres long, and carry over 6,000 men and more than 90 aircraft.

Other aircraft carriers are much smaller. The modern, Russian carriers, known as Kievs, weigh about 32,000 tonnes and carry over 20 helicopters and 12 vertical take-off planes. However, the Kiev carriers are no match for the vastly superior US carriers.

Probably the most famous British example of an aircraft carrier is HMS *Invincible*, said to be one of the largest warships in the world to be propelled by gas turbines. Over 206 metres long, it can carry 950 men

INTO THE FUTURE

SUPERSONIC FLYING SUB



Alan Burrows

▲ *The aerosub, or flying submarine, is one of many exciting possibilities for future sea weapons, with a greater potential even than Exocet class missiles.*

▲ *Aerosub will fly to within a few hundred kilometres of its target, then plunge into the water to avoid enemy radar – moving as fast under the sea as above it.*

▲ *Accelerating to supersonic speed when approaching its target, the aerosub will burst out of the water and deliver its fatal charge with precise accuracy.*

and 25 aircraft, and reaches a speed of 28 knots (52 km/h). At a mere 16,000 tonnes, compared with the massive Nimitz carriers, *Invincible* reflects the recent emphasis on lightweight design.

Standard warships

In the past, battleships and cruisers relied on massive armour plating for protection. Now the emphasis is on light weight and agility, with greater reliance on speed and electronic detection and anti-missile equipment for keeping out of trouble.

The very first nuclear submarine, USS *Nautilus*, was built in 1955, and travelled 530,000 km using only 5 kg of nuclear fuel (a car covering the same distance would have used about 38,000 litres of petrol). In the 30 years that have passed since then, these vessels have become the most independent, formidable and dangerous craft at sea. Independent because they can spend indefinite periods of time with no outside contact (their nuclear reactor core needs replacing only every few years); formidable because of the sophisticated equipment that runs them; and dangerous because of their weapons – ballistic missiles armed with dozens of nuclear warheads.

Underwater prowlers

Modern nuclear submarines are built primarily for speed. The fastest in the world are the USSR's Alfa class, which can reach a maximum speed of 42 knots (78 km/h); but there are many others which reach speeds of over 30 knots (56 km/h).

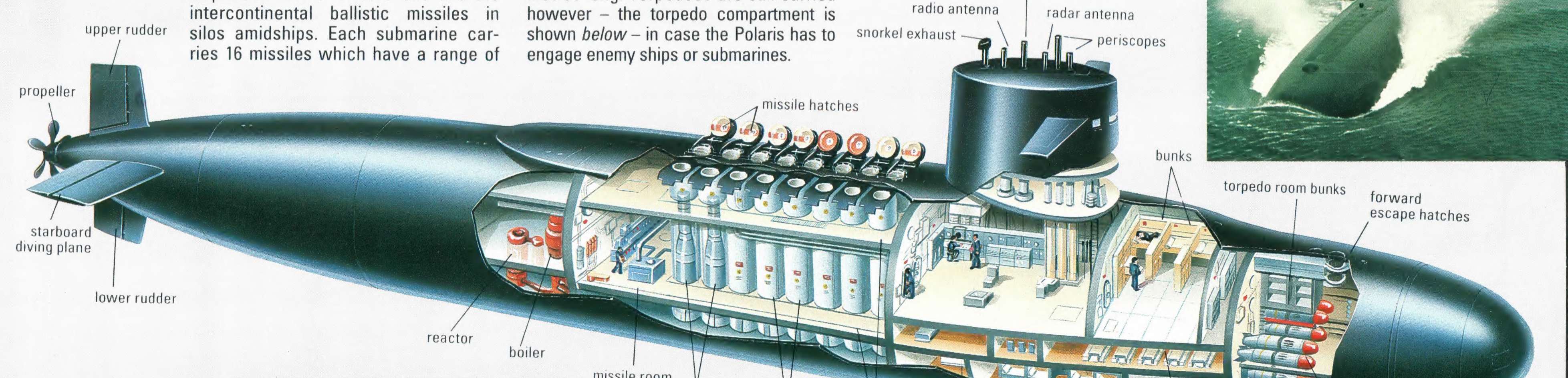
Nuclear subs generally fall into two types – the large SSBNs (ballistic nuclear submarines) and the smaller 'hunter-killer' fleet submarines. SSBNs carry sea-launched nuclear missiles that can be fired underwater, carrying warheads to targets that may be thousands of kilometres away. 'Hunter-killer' types are used to track SSBNs down. These are faster, and are equipped with sensitive sonar to detect the unique 'noise signature' of other submarines, which they stalk and destroy with torpedoes.

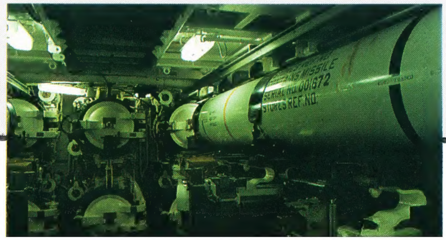
If a nuclear sub runs too shallow, it will break the surface and be seen; too deep and it will be crushed by water pressure. So the sub's exact position is constantly monitored by the Submarine Inertial Navigation System (SINS). This calculates movement in all directions, ensuring that the sub does not move too far off the correct path. It is made up of a series of gyroscopes, and can operate for many days underwater. However, SINS needs to be checked occasionally against the positions of the stars or a point of land.

***A British nuclear** sub, HMS* Conqueror, *on the ocean surface. These 'hunter-killer' subs can remain submerged for years. During the Falklands War, it was* Conqueror *that sank the* Belgrano.

THE POLARIS SUBMARINE

A cross section of the Polaris shows torpedoes at the forward end and the intercontinental ballistic missiles in silos amidships. Each submarine carries 16 missiles which have a range of up to 4,500 km. Each missile is about 10 metres long. Torpedoes are still carried however – the torpedo compartment is shown *below* – in case the Polaris has to engage enemy ships or submarines.





Ian Stephens

A Tyne class lifeboat *lifts out of the water, reducing the drag on its hull, as it builds up to its maximum speed of 18 knots (33 km/h).*

RESCUE AND SURVIVAL

IN JULY 1987, A RECORD-breaking attempt to cross the Atlantic by hot-air balloon nearly ended in disaster.

Towards the end of the momentous journey, only a few kilometres off the coast of Scotland, the balloon's pilots, Richard Branson and Per Lindstrand, were forced to abandon their craft, the *Virgin Atlantic Flyer*, and leap into the sea.

THE ARUN CLASS LIFEBOAT

One of the largest, fastest and most manoeuvrable types of lifeboat in service is the Arun class. At its top speed of 18.5 knots (34 km/h), it can travel 230 km to the scene of an emergency and return to base. The coxswain can steer the vessel from inside the wheelhouse or from the flying bridge. Two cabins are equipped for the care of survivors.

Rex Features

Rex Features

A ship in distress *is located and survivors wait to be rescued. One crew member called a 'diver' in the Navy is winched down on a rope. Able bodied survivors will be winched back in a harness. The winch is operated by the radar operator or navigator.*

A stretcher *is sometimes necessary to air-lift injured survivors. The helicopter is able to winch up 270 kg – about the weight of four adult men.*

Within minutes, their SOS call had coastguard officials alerting RAF station Dunfermline. Within half an hour, Branson was lifted from the sea by a Lynx helicopter from HMS *Argonaut*. Lindstrand was picked up by a lifeboat.

24-hour alert

In order to work hand in hand, the different rescue services are connected on land by telephone and telex lines, and at sea by a multi-channel radio service. They are on the alert 24 hours a day.

Distress calls can be sent in different ways, but radio-telephone calls on specially reserved channels are the most usual. Automatic beacons powered by batteries or solar cells are carried by ships' lifeboats and are even fitted to some lifejackets.

Signalling lamps, torches or emergency transmitters can send the Morse signal SOS – three dots, three dashes, three dots – the internationally recognized call for immediate assistance. In time, however, Morse signals will be replaced by the Global Maritime Distress and Safety system.

Lifeboat rescue

In the UK, the Royal National Lifeboat Institution (RNLI) provides a 24-hour sea rescue service around the coasts. It has 204 lifeboat stations, 128 large lifeboats (10–21 metres long), 133 smaller ones (5–6.5 metres long) and 133 inflatable lifeboats. Inflatables have been introduced to deal with the growing number of incidents involving water sports enthusiasts, mainly in inshore waters. The inflatables are virtually unsinkable and fast. Twin-engined versions can reach 30 knots (55 km/h).

The RNLI's sophisticated high-performance craft can get to a vessel in distress up to 50 km from the shore within four hours (or as little as two hours for some of the faster boats).

Many of today's lifeboats are 'Fast Afloat Boats' (FABs), which means that they are kept afloat in a harbour or inlet, rather than launched down a slipway.

FERRY DISASTER

At 7.20 p.m. on 6 March 1987, a dredger captain in the Belgian port of Zeebrugge radioed that the British ferry *Herald of Free Enterprise* was capsizing. The Belgian Sea Rescue Service co-ordinated the massive rescue operation that instantly swung into action. A Sea King helicopter, tugboats, other small craft and divers helped save 300 of the 500 passengers.

Frank Spooner Pictures

Rescue by air

The fastest rescues of all are carried out by helicopters. In the UK, they are mostly operated by the Royal Air Force and Royal Navy.

A Wessex helicopter can normally carry ten rescued persons in addition to its three-man crew. A Sea King can take 16 people as well as its four-man crew. But in an emergency, either type can take far more people on board, jettisoning fuel if necessary to lighten the craft.

Just amazing!

ENDURANCE AT SEA

MAN'S CAPACITY FOR SURVIVAL AT SEA IS REMARKABLE. IN 1942, A SHIP'S STEWARD, POON LIM, LIVED FOR 133 DAYS ON A RAFT WITH ONLY 50 DAYS' WORTH OF FOOD AND WATER, AFTER HIS SHIP WAS TORPEDOED.

Paul Raymonde

KEYS TO SURVIVAL

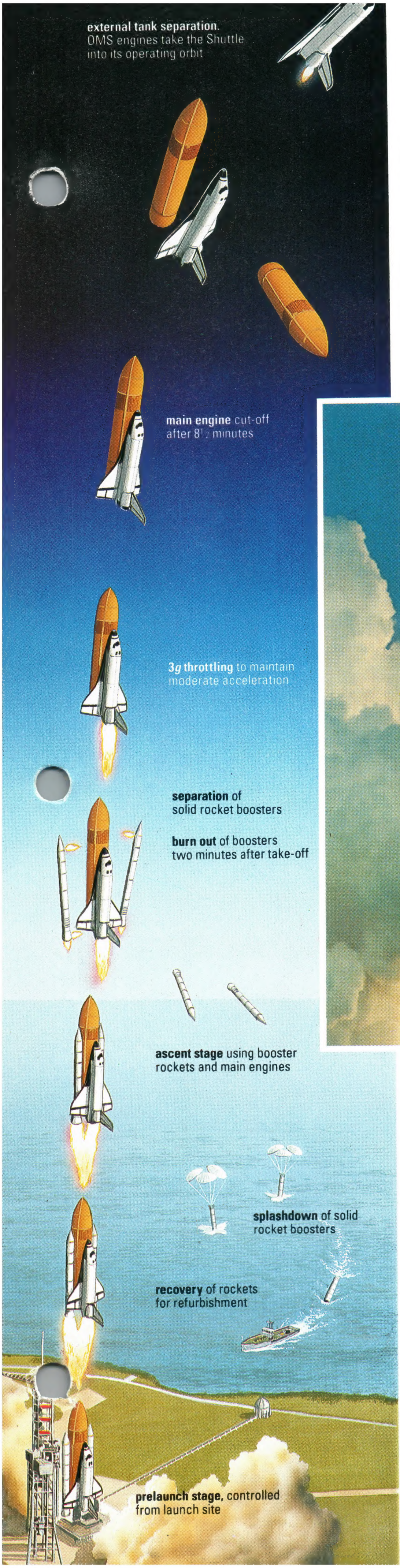
If you have to wait for rescue after finding yourself adrift, or after capsizing follow these four basic survival rules:

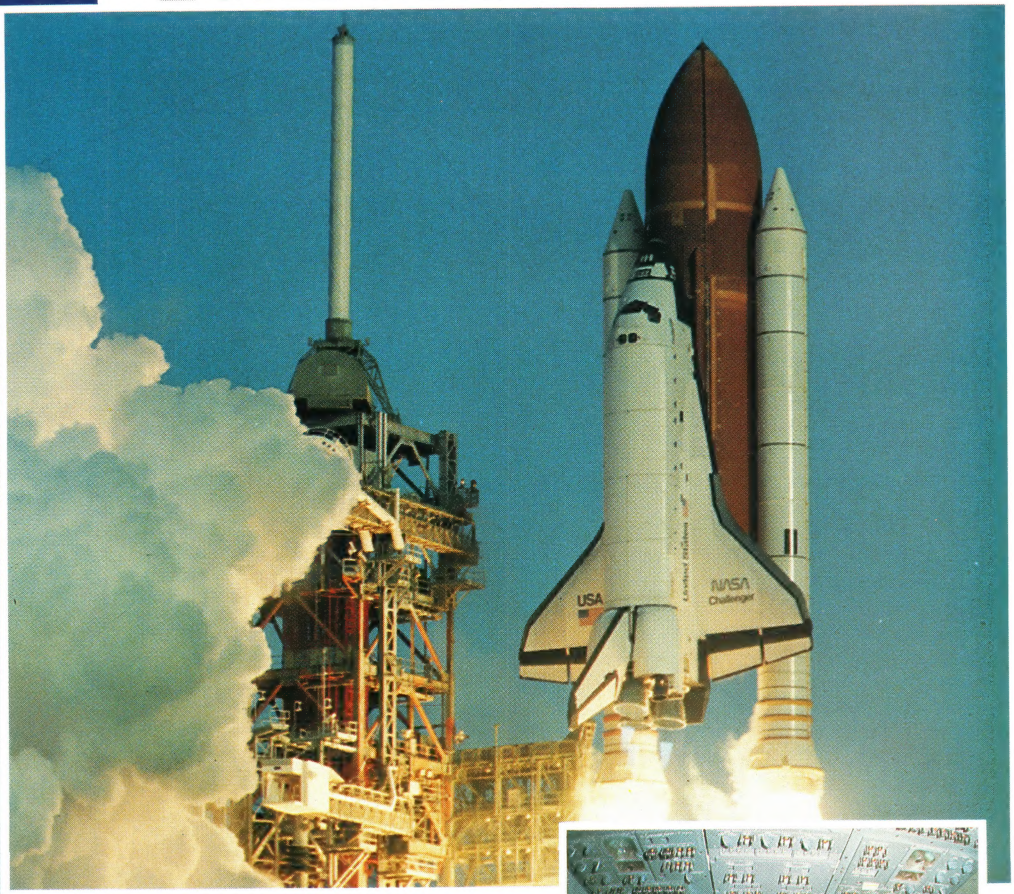
- Stay with the craft. Not only will it shelter you, it will give you something to hold on to so that you can conserve your energy.
- If you have to enter the water, try to do so gradually. The shock of cold water can be dangerous.
- Stay warm. Don't shed clothes and move as little as possible (water moving past you takes heat away). Keep your face as dry as possible. If you're with others, huddle together.
- Don't tire yourself. Try to move as little as possible, and tread water rather than swim any distance.

FLYING THE SHUTTLE

THE RE-USABLE SPACECRAFT

SATELLITE REPAIRS · ORBITER LANDING





NASA

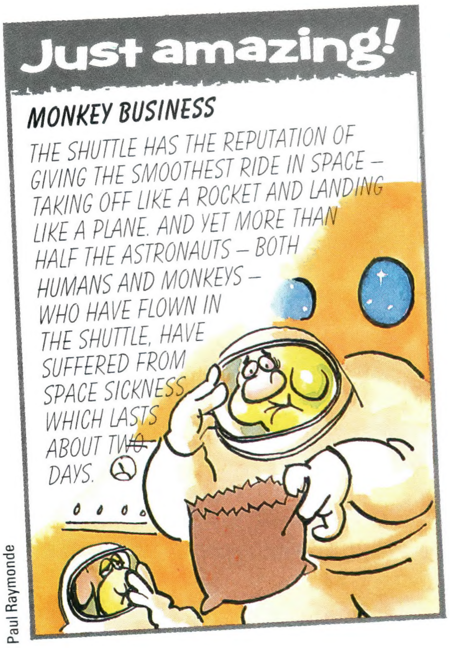
The Shuttle's flightdeck *is dominated by the flight computer, which reads out to the three central screens. Shuttle astronauts wear space suits during launch and landing in case of emergency.*

GUSHING A WHITE GEYSER OF flame, the USA's Space Shuttle slowly lifts clear of its launch tower – then rapidly accelerates. Just eight minutes later, bearing its crew and cargo, the Shuttle reaches Earth orbit about 200 km above the ground.

Unlike an ordinary rocket, the Space Shuttle is designed to be used over and over again. It has four main parts: the orbiter (shaped like a chunky aeroplane), two solid rocket boosters (SRBs), and a large external tank.

At lift-off, the twin SRBs and the three main engines at the back of the orbiter all fire together. The SRBs provide the real 'muscle' to get the Shuttle off the ground and build up speed. Two minutes into

David Parker



Paul Raymonde

the flight, their fuel is used up and they fall into the sea on parachutes.

Meanwhile, gulping in liquid fuel from the external tank, the orbiter's three main engines continue firing for another six minutes. By the time they cut out, the orbiter is at the edge of space and ready to make its final course correction to enter Earth orbit. The external tank is jettisoned and burns up as it hurtles back down through the atmosphere. It is the only part of the Shuttle that cannot be re-used.

Tasks in Orbit

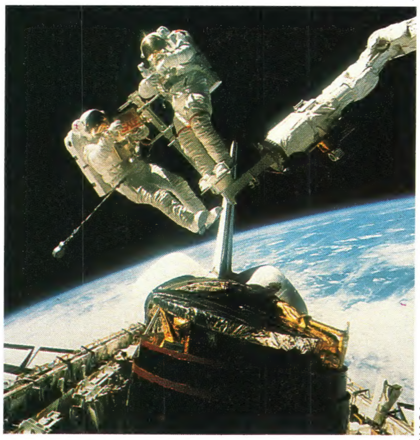
Usually between five and seven crew members are involved in a Shuttle mission. Once in space, their job may be to launch satellites out of the orbiter's payload bay, or even go outside to fix a spacecraft.

Using a Manned Maneuvering Unit (MMU) – a special backpack fitted with small thruster jets – an astronaut can move freely up to about 100 metres away from the Shuttle. In this way, satellites may be repaired 'on site' or placed into the Shuttle's hold and brought back to Earth.

For launching satellites and doing other heavy work, the Shuttle's payload bay is equipped with a robot 'manipulator arm' that can be operated by a crew member from inside the orbiter. Often, a communications satellite has to be placed 35,900 km above the equator, where it will orbit in time with the Earth's spin. The Shuttle, however, is limited to orbits below 1,100 km. Therefore, the satellite is sent spinning gently up out of the payload bay. Then a booster rocket fitted to the satellite fires and lifts it into the required orbit.

A Shuttle mission may last up to 30 days. Then the orbiter glides back down to Earth. Special thermal tiles help protect the spacecraft as its surface heats to 1,500°C, when it plunges into Earth's atmosphere at a speed of 27,000 km/h.

Finally, the orbiter lands on a runway as if it were an ordinary plane. A specially adapted jumbo jet then carries the orbiter piggy-back to its launch site to be made ready for the next flight.



NASA

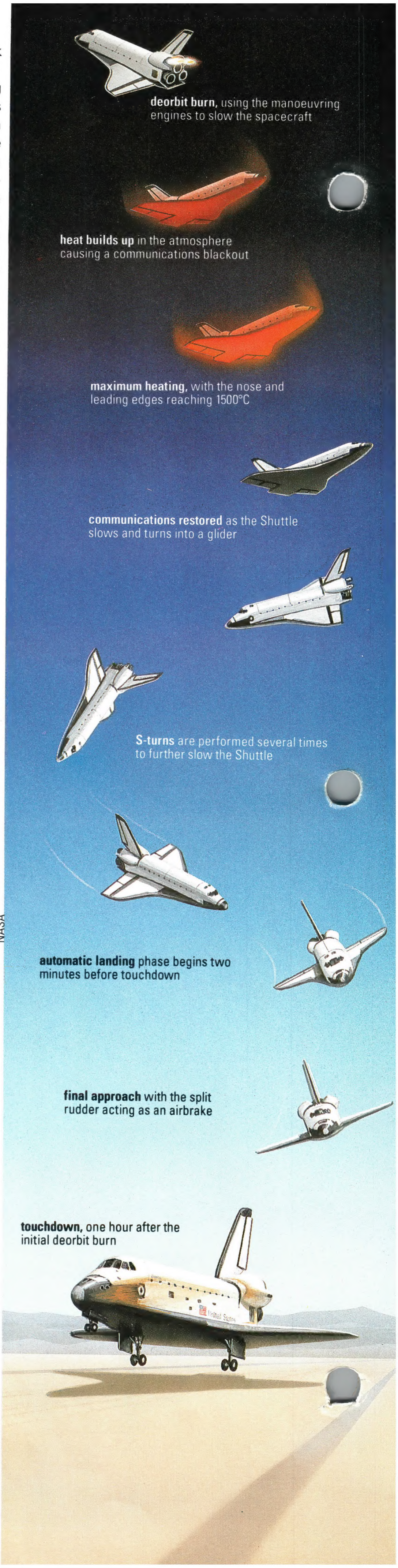
Stepping out *into space, two astronauts from* Discovery *retrieve a satellite that was stranded in orbit.*

DISASTER IN THE SKY

Frank Spooner Pictures

On the afternoon of Tuesday, 28 January 1986, 73.6 seconds after launch, the Shuttle, *Challenger*, exploded, killing all seven crew members. The cause of the explosion is thought to have been a faulty seal on one of the booster rockets, which allowed the hot gases being burned to escape. These gases, at 3,100°C, instantly caused a massive explosion that blew the Shuttle apart. The two boosters continued flying until they were destroyed seconds later.

The *Challenger* disaster brought the Shuttle programme to a temporary halt while the boosters were redesigned. A new orbiter, *Endeavour*, was built to replace *Challenger* at a cost of $2 billion; its first flight was in May 1992.



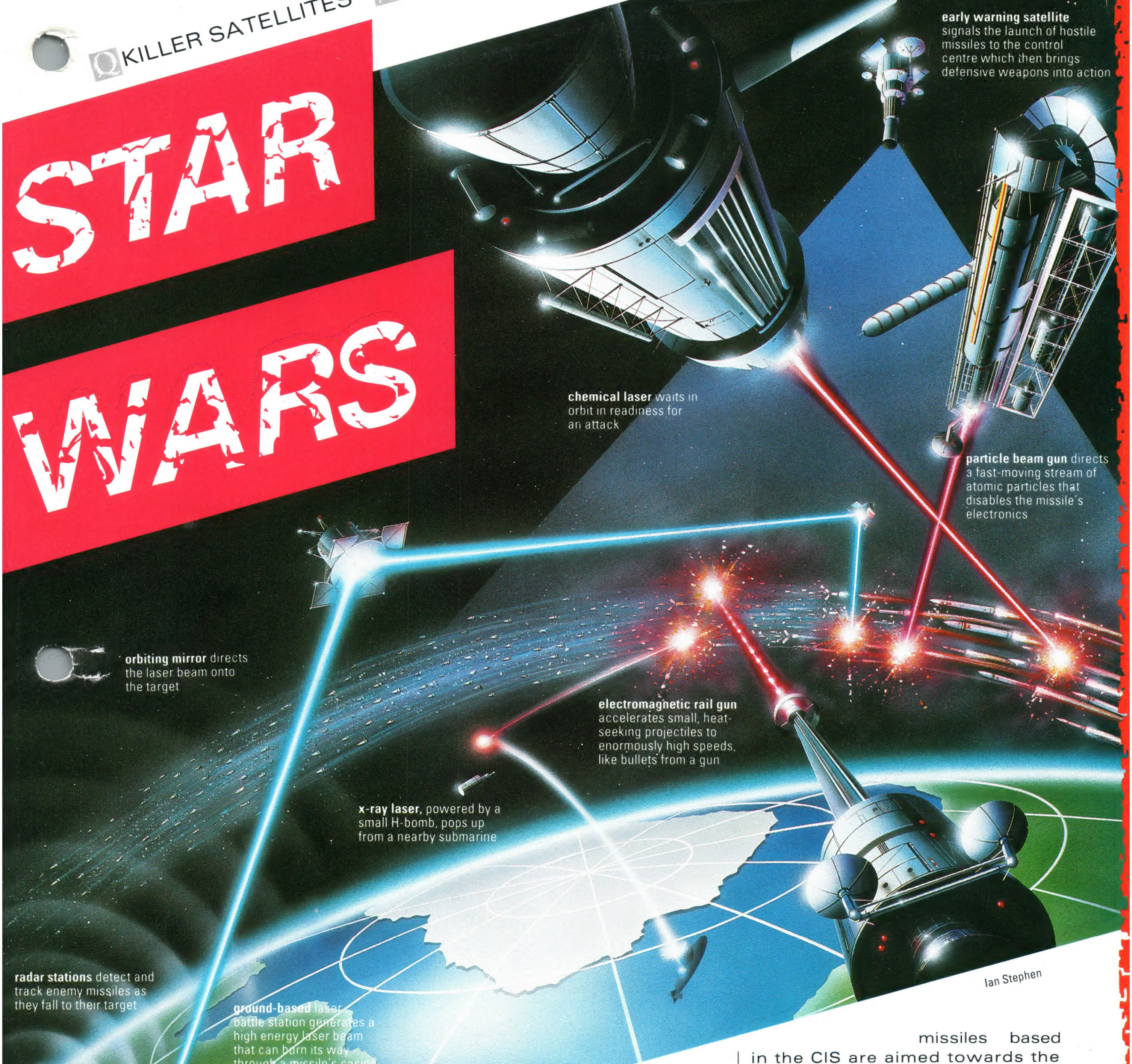
David Parker

X-RAY LASERS

INTERCEPTOR ROCKETS

KILLER SATELLITES

STAR WARS



AN ALARM BELL suddenly sounds in the secret underground headquarters of America's defence command. The United States and its allies are under massive nuclear attack.

Speedily, orders are sent up to a fantastic array of weaponry circling around the Earth. Laser beams flash and interceptor rockets soar from their launch-pads in an all-out effort to destroy the enemy missiles before they strike their targets. Within just half an hour, World War III is over.

In 1983, President Reagan announced that it would be a goal of the United States to develop a space-based defence system against possible nuclear attack. Officially called the Strategic Defence Initiative, or SDI, the scheme immediately became better known as 'Star Wars'.

About 2,000 intercontinental missiles based in the CIS are aimed towards the United States. Some of these are capable of carrying six to 10 separate warheads, which are ejected with several decoys to confuse the enemy. The warheads are guided independently to their targets, taking only 30 minutes to make the 8,000 km journey. The Star Wars system is designed to ensure that no Russian or other warheads arrive on American soil – each missile to be blown to pieces while still in flight.

Spy satellites and ground-based radar would provide the first warning that a nuclear attack was underway. Their data would be fed automatically to a group of powerful

computers at defence headquarters. Information on the position and course of each enemy missile would be worked out and passed on to a series of computers located around the United States. From these, commands would flash up to the various Star Wars weapons waiting in Earth orbit.

Less than five minutes after being launched, the first wave of enemy missiles would be met by a volley of laser beams. Lasers send out a powerful concentrated beam of light that can burn its way through a missile's casing. Laser beams travel at the speed of light, 300,000 km/s. Some of the lasers would be carried on board spacecraft flying high above the Earth's surface.

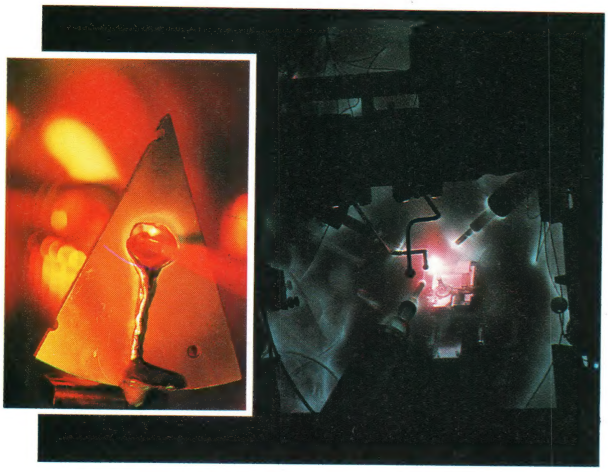
The huge space-based lasers would lock on to their targets with pinpoint accuracy and fire concentrated bursts of energy at them. At the same time, beams from ground-based lasers would hit five metre wide orbiting mirrors, which would reflect the powerful, destructive laser beams on to their targets.

As they hurtled above the atmosphere, hundreds of the enemy missiles might be destroyed by the defensive lasers. Yet hundreds more would escape. Other Star Wars devices would then come into play. Bizarre weapons known as rail guns would use a long chain of strong magnets to shoot out projectiles at very high speeds.

Powered by a nuclear reactor, each rail gun would be capable of firing at least twice a second, identifying the target using heat-seeking sensors. The charged-particle guns would send beams of atomic particles that could penetrate the missile and disable the electronics inside.

Enemy missiles that managed to evade both the lasers and the back-up equipment would be met by a final salvo of interceptor rockets. Launched from the ground, these interceptors would simply ram into and destroy any objects in their path. This, though, would be very much a last-ditch effort. In theory, the SDI lasers should be all that is necessary.

Yet, theory is all that Star Wars is. Most of the technology for an SDI system has still to be developed. So far, no weapon like a rail gun has been built and no-one knows how well it would work in practice.



Alexander Tsiaras/SPL

SPL

***Beam guns** set up in the laboratory. A particle beam gun (inset) burns a hole in a piece of aluminium. This kind of beam can destroy electronic circuits within a missile's casing. It is also unaffected by the Earth's magnetic field. This means it can be fired in straight lines at very distant objects.*

A real possibility?

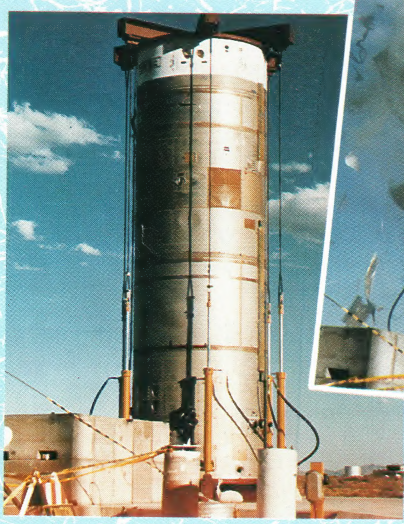
However a limited SDI programme known as GPALS (Global Protection Against Limited Strikes) is proceeding satisfactorily. It is a space-based system called 'Brilliant Pebbles', consisting of surveillance sensors. It fires solid objects at great speed into the path of incoming missiles, and uses ground-launched, anti-ballistic, missiles as a last line of defence.

Another argument against Star Wars is that other countries might develop 'killer satellites'. These orbiting spacecraft would destroy the surveillance satellites, lasers and other weaponry upon which the SDI system depends. However, with the end of the Cold War, there is the possibility of US-Russian cooperation in Star Wars systems.

STAR WARS SPIN-OFF

Some of the equipment currently being researched for SDI could eventually find a peaceful use. One team of NASA scientists, for instance, has suggested that a rail gun could be employed to hurl small probes into space. Each probe, equipped with advanced micro-circuits might be no bigger than a coffee jar and weigh only 1–2 kg. Catapulted away from the Earth at a very high speed, such a tiny spacecraft would take only a few years to reach Saturn.

LASER POWER



US Department of Defense

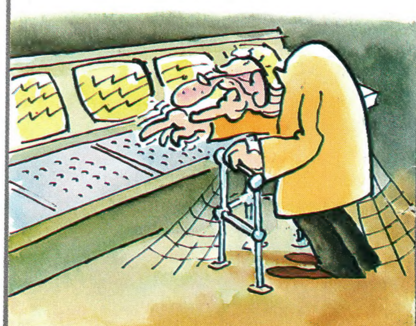
Before: Part of a Titan I Missile sits in the New Mexico sun . . .

After: . . . and is blown to smithereens by a high-energy laser beam. This test proved the power of MIRACL, the Mid-Infra-red Advanced Chemical Laser, one of the lasers to be used in SDI.

Just amazing!

WORKING OVERTIME

TALK OF STAR WARS IS ALL VERY WELL, BUT TO PROGRAM ALL THE SUPER-COMPUTERS FOR EVEN THE WESTERN DEFENCE SYSTEM WOULD TAKE ONE MAN 30,000 YEARS TO COMPLETE.



Paul Raymonde

INSIDE RADIO AND TV

Sony Jumbotron – the world's largest TV – on display at the Tsukuba Expo 85 in Japan. At the other end of the scale, the Japanese launched a 'walkman' TV, very much like a personal stereo, in 1988.

Spectrum Colour Library

IMAGINE A TELEVISION SET, covering one entire wall of your living room. Imagine being able to view two or more programmes at once – watching an adventure film while keeping an eye on a football match.

Soon all this will become possible through advances in electronic technology and production techniques.

Since it started in the 1930s, television broadcasting has made tremendous technical progress. Today, it can entertain, inform, and educate us. Into our homes it brings pictures and sounds of events from wars to royal weddings, from sporting competitions to the drama of a hijacking. Not only can we view such events first hand, but with the addition of videotape, we can freeze, replay and even zoom in to particular sections of the picture. Soon these facilities may even be incorporated into the TV set itself.

Radio, too, has emerged as a vital information medium in the modern world. Indeed, it was the invention of radio that eventually led to the birth of television.

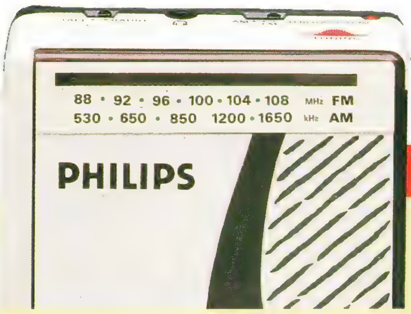
Radio broadcasting

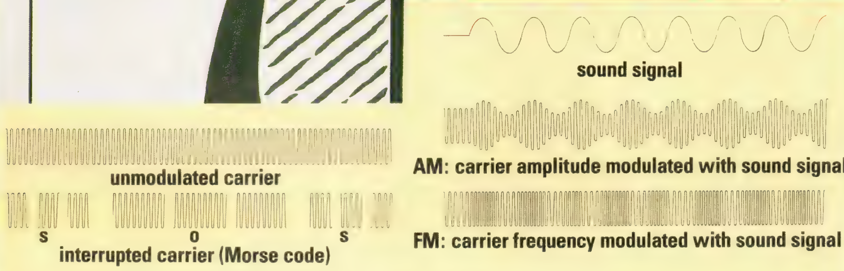
By comparison with the electric telegraph, and even the telephone, radio seemed to offer an almost miraculous way to communicate. Silent and invisible, radio waves could carry Morse code signals through the air without any need for electrical cables. In 1896, the Italian inventor Guglielmo Marconi became the first person to send 'wireless' signals over a distance of several kilometres. Five years later, he beamed a message all the way across the Atlantic. Thus came about what in Britain was called 'wireless telegraphy' and in the United States 'radiotelegraphy', or 'radio' for short.

It was soon discovered how to use radio to transmit not just coded signals, but also speech and music as well. The trick was to use the sound signals from a microphone to vary the radio waves in some way. The radio waves thus 'carried' the sound information. This is why engineers refer to the radio signal as the 'carrier'.

The first method used to superimpose sound signals on radio waves was amplitude modulation

SIGNALS BY RADIO





A radio transmitter normally sends out a continuous signal. Morse code can be transmitted by switching the transmitter on in short and long bursts to produce 'dots' and 'dashes'. To transmit speech or music, the sound signal is made to modulate (vary) either the amplitude or the frequency. This produces an amplitude-modulated (AM) or frequency-modulated (FM) transmission.

Mark Franklin

(AM). The sound waves were used to vary the amplitude (strength) of the carrier. Amplitude modulation is still used in radio today. Depending on their wavelength, AM radio broadcasts may be short wave (SW), medium wave (MW), or long wave (LW).

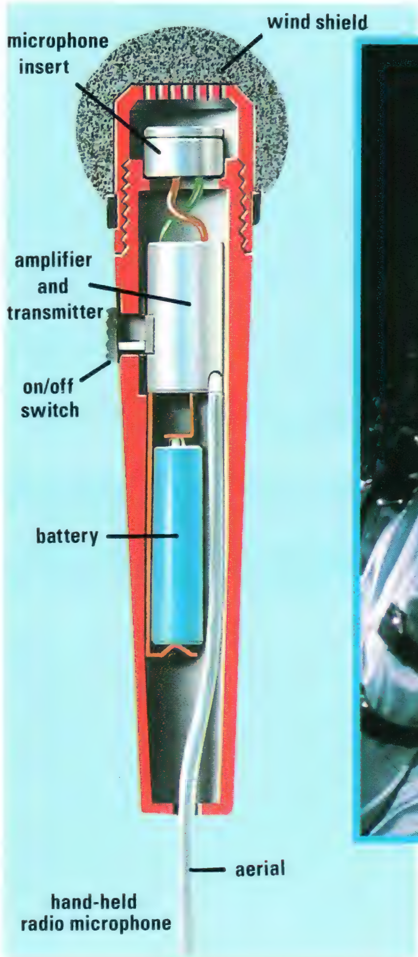
Since the end of World War II, frequency modulated, or FM, radio has also become popular. In frequency modulation, the sound signal varies the frequency of the carrier – the rate at which the radio waves are produced. Unlike AM radio, FM is generally unaffected by interference from other radio stations, motor cars and lightning. Try tuning first into an AM station and then into a station on the FM band. The difference in sound quality will be obvious immediately.

Suppose you are listening to someone talking on the radio. Whatever form of modulation is used, the radio signal – the modulated carrier – is radiated from a transmitting aerial.

The aerial of a radio receiver picks up radio signals from thousands of stations and turns them into tiny electric signals. A tuning circuit in the receiver allows you to select the signal you want. Other circuits strengthen the signal and demodulate it – that is, extract the sound signal from it. This is then further strengthened and passed through a loudspeaker, which thus reproduces the original sounds from the radio studio.

SMART RADIO

With so many radio stations to choose from, it is often difficult to find the one you want. The Radio Data System (RDS) provides a solution. The transmission carries an extra, inaudible signal containing data about the programme. Inside the receiver, a special microchip sorts out this data and displays it on a small indicator panel. The receiver will automatically switch to the strongest signal if more than one transmitter is broadcasting the programme you want.



Rex Features

***Radio microphones** are popular with rock stars as they have no trailing cable to restrict their movements. Inside the microphone case is a tiny transmitter, which sends the sounds via a short aerial to a nearby receiver connected to the amplification system.*

Inside the box

Television, too, makes use of radio signals that are sent through the air. The difference is that a TV transmission carries both sound and vision signals. The sound signals come from microphones, and the vision signals are formed in the television cameras. Vision signals contain all the information needed to reproduce pictures on a TV screen.

A roof-top aerial picks up the broadcast TV signal, converts it to a small, varying electric current, and then passes this to the television set. The sound portion of the signal is played through a loudspeaker while the picture information controls the way in which the image is re-formed on the screen.

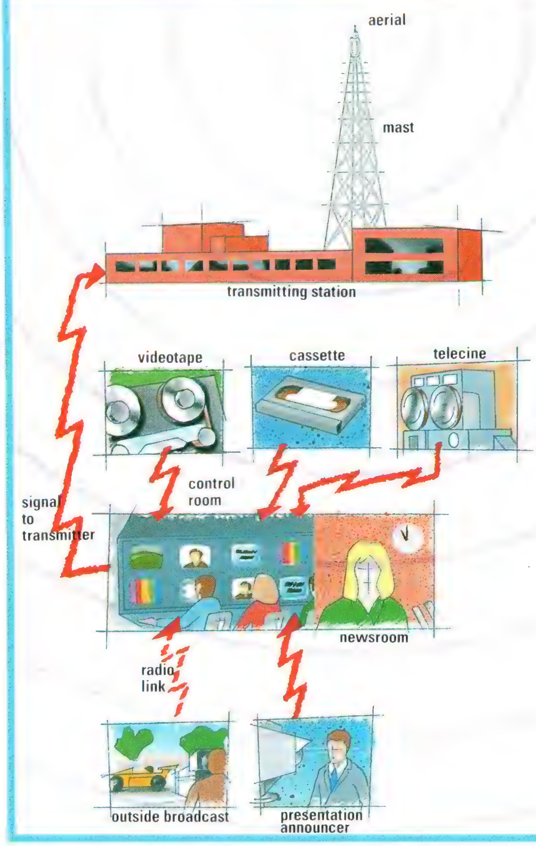
Spitting out a stream of tiny particles called electrons, the electron gun inside a black-and-white

CB JARGON

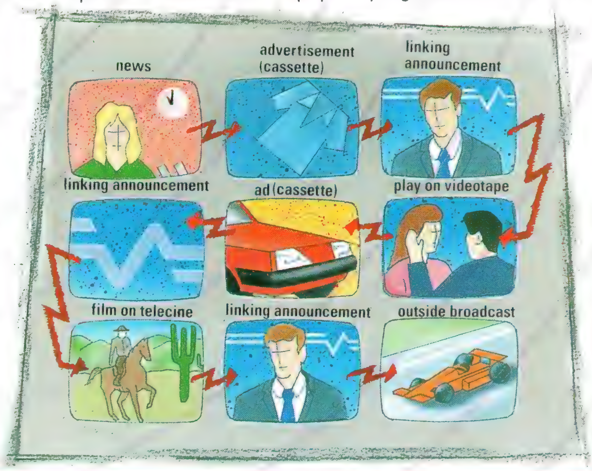
Daily Telegraph Colour Library

bandage factory hospital
bear in the air police helicopter
body lotion drink
bone box ambulance
box on wheels hearse
brain bucket crash helmet
brain-donor idiot
bubble trouble puncture
bumble bee motorbike
carpet crawler young child
chew and choke cafe
coffin boffin old person
confetti snow
dandruff snow
dinosaur juice petrol
fishtank bus
fly in the sky aircraft
fuzz buster radar detector
greasy side up overturned vehicle
maniac garage mechanic
motion lotion petrol
nosebag take-away food shop
one-way taxi hearse
panty stretcher fat person
plain wrapper unmarked police car
Rembrandt house painter
press the sheets go to sleep
roach coach garbage truck
run out of road have accident
seat cover passenger
skid lid crash helmet
splat hat crash helmet
thumb-job hitch-hiker
zeds sleep

HOW THE IMAGE ARRIVES



The pictures we see on our TV screens come from many different sources. Items that come to us 'live' — at the time they are made — include news material, weather forecasts, and linking 'presentation' announcements between programmes. Outside broadcasts, such as live sports events, are often beamed to the TV studios by special radio-link equipment. However, most of the programmes we watch are pre-recorded. Films made for the cinema are played to us on telecine machines. Television drama is replayed on videotape machines, and advertisements come to us from video cassette machines. Signals from all these sources pass through a control room to the TV transmitter, which beams the programmes to our homes.



Yanos Maffy

television picture tube rapidly 'scans' the whole surface of the screen, line by line. The inside of the screen is coated with a chemical called a phosphor, which glows according to the strength of the electron beam striking it. The vision signal regulates the strength of the electron beam and thus controls the brightness of each point on the screen as the beam passes over it. In this way, the vision signal, representing the brightness of each point in the original scene, produces a replica of it on the screen.

__Dish antennas__ for receiving satellite TV broadcasts are becoming a common sight on private homes in Europe. The cost of this new technology has decreased considerably in recent years, and satellite services in the UK are about to expand even more.

Alex Bartel/SPL

__TV satellite__ broadcasting may be relatively new to Europe, but India has had a system of direct broadcasting since 1975. A dish antenna (inset) beams the signals to a communications satellite, which re-transmits them to receiving dishes nationwide.

Hutchinson Library

Twenty-five times a second, the electron gun scans the entire screen, creating a slightly different image each time. To the eye, the result is a continuously moving picture.

Colour television works in a similar way to black and white TV. But the vision signals contain information on colour – not just brightness.

Instead of just one electron gun, the tube in a colour TV set uses three – one for each of the primary colours, red, green and blue. Arranged along each line of a colour TV screen are hundreds of groups of three phosphor dots, which glow red, green or blue when struck by an electron beam. Beams from the three guns scan the screen together, each striking only one type of phosphor dot. Thus the three beams each control one of the primary colours in the picture. Different proportions of the three colours produce different colours, when viewed from a distance. This is why a multicoloured picture can be reproduced from dots of just three primary colours.

Cable and satellite TV

For a long time, cable has been used to carry TV broadcasts to remote areas or to blocks of flats that would otherwise need large numbers of aerials. Recently, though,

TDAF/Network

***Giant TV screens** allow everyone to get a close-up view at open-air rock concerts and sports events. Popularized in the US, these huge sceeens allow instant replay, commentary and advertising.*

Hittori UK LTD

***Miniature TV sets** were just a dream in the days when the average receiver was the size of a large cupboard. But the invention of the microchip, and vast improvements in display technology, have made the pocket TV set a reality.*

entirely new TV stations have been set up that broadcast exclusively by this means. Cable also makes possible interactive TV. In this, viewers can take part in quiz shows or live debates, simply by pressing buttons on a hand-held unit.

Another recent development is direct broadcasting by satellite, or DBS. By means of a small dish aerial, TV signals beamed out from all parts of the Earth, and relayed by communications satellites, can be picked up in the home. Already both satellite and cable TV are greatly increasing our choice of television programmes, adding specialist channels for news, sport, films, music and weather to those that are already available.

With the push of a button, today's television can be switched from its usual role to a device for retrieving information. All you need to make use of this facility is a remote-control device and a TV fitted with circuits for decoding teletext signals.

Teletext consists of hundreds of screen-sized pages of information. News summaries, sports results, programme guides, recipes, weather forecasts, travel information, and even jokes and brain-teasers can be called up almost instantly.

Just amazing!

CHILD'S PLAY

TV DRAMA IS NOTORIOUSLY VIOLENT. BY THE TIME HE OR SHE IS 16, THE AVERAGE AMERICAN CHILD WILL HAVE SEEN 50,000 TV MURDERS AND 200,000 ACTS OF VIOLENCE.

Paul Raymonde

THE PRINT BUSINESS

Sporting Pictures

A reporter and photographer at the match send in an article and pictures to the magazine.

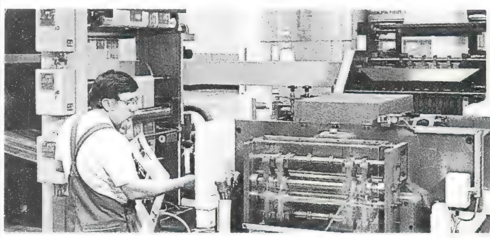
The Independent

Journalists edit the article and pictures to fit the page design.

The pictures and typeset article are separated into four basic colour plates.

Shoot Magazine

The printer uses all four colour plates to print from.



The finished printed pages are folded and bound into the magazine that goes on sale.

Shoot Magazine

***That winning kick** is captured for ever in print. From the match, the reporter sends in the story and the photographer, the pictures. Journalists refine the words and pictures ready for publication. The text is set in type, while the pictures are 'colour separated'. At the printers, they all come together in the final printed page.*

MORE INFORMATION TODAY is available instantly at the touch of a button. But in spite of this, books, magazines and newspapers remain a popular form of communication.

Until the late 1960s, many of the techniques for printing had changed only slowly from one generation to the next. But now, increasingly, it is the computer and the laser that print the material we read.

The coming of colour

Colour books and magazines appeared only in the last 50 years. Look at the illustrations on this page with a magnifying glass, and you will see they are made up of thousands of tiny dots. Just four different colours are used – the primary colours, yellow, magenta and cyan, together with black. From different combinations of these, any other colour can be printed.

To print in colour, the original colour picture is first put through a 'scanner'. This is a highly sophisticated electronically controlled machine that breaks down the picture into the four basic colours. Each colour is also broken down into a dot pattern. The bigger the dots, the denser the ink on the page and the darker the image appears at that point. Light areas of colour are represented by small dots.

The four colour-dot patterns are printed on four separate films and these, in turn, are used to transfer the dot patterns on to individual metal plates. The dots on each plate are inked in their respective colours and are then transferred – printed – one over the other, so that, together, they once again form the whole colour picture.

Hot metal type

Until just a few years ago, all national newspapers in Britain were printed by machinery that was nearly 60 years old. The article that a journalist had written was prepared for printing on what was called a Linotype machine.

An operator tapped out the

words at a keyboard similar to a typewriter's, which translated them into a series of punched hole patterns in a tape. When this tape was fed into the machine, it was 'read' and solid lines of type were built up from a pot of molten metal – hence the name 'hot metal'.

The lines were all stacked in type holders called galleys and arranged as they would appear on the printed page, together with any plates for printing pictures. This arrangement of type and plates, called a forme, was clamped together in a metal frame called a chase. Printing plates were then made from impressions of the formes. These plates were wrapped around cylinders, inked and used to print the pages.

Some printers still use Linotype, but it is quickly giving way to computerized typesetting and printing. Here, the text to be printed is keyed in at a computer workstation and displayed on a television-like screen. Any changes to the text are easily made at this stage, by the reporter or the editor, with a word processing program.

Electronic printing

The computer is used to select exactly how the edited text will appear on the finished page – the size of letters, the arrangement of the text, and so on. This is continually monitored on a high resolution TV screen. When everything is finalized, the computer sends digital signals to a laser to print the page on to light sensitive film. This film is used to make the final plate.

Computers are also used in the final printing process. They can be used to monitor and adjust the fine tuning required right until the printed page rolls off the press.

Paul Raymonde

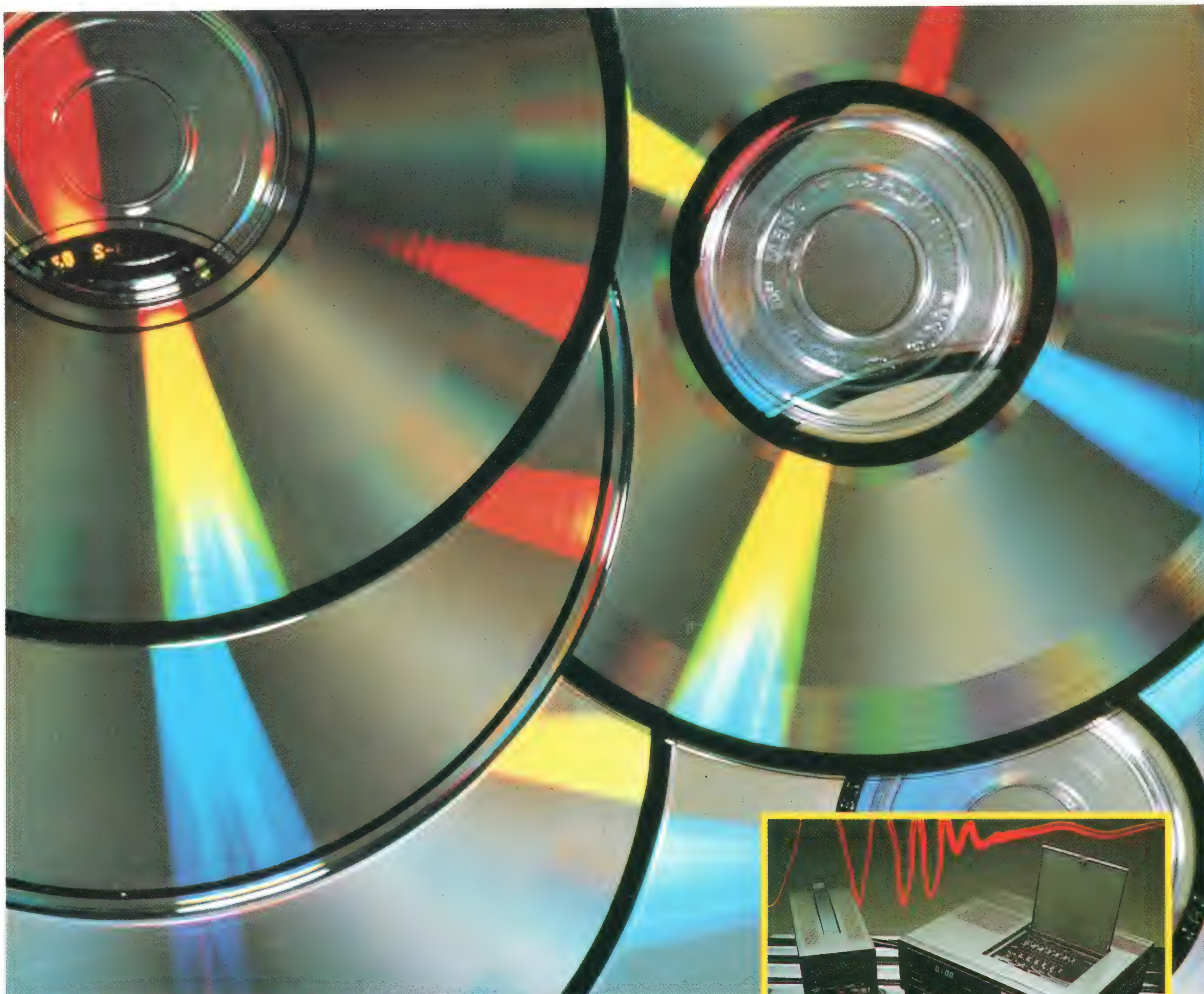
Mark Franklin

Full-colour *pictures are usually reproduced in magazines and books using only four colours – yellow, magenta, cyan and black. An electronic scanner first produces four dot patterns representing the yellow, magenta, cyan and black content of each part of the picture. Each of these patterns is recorded as a black image on a sheet of film. These images are used to make printing plates that apply each colour ink in turn to the paper to give the final full-colour picture.*

ELECTROSTATIC PRINTING

Photocopiers are also used for printing. Some machines reproduce in colour and even add it where needed. To print, the original is projected on to a drum coated with selenium – a substance that loses its electric charge when light shines on it. The pattern formed on the drum attracts powdered ink, which is then transferred to the printing paper.

Canon (UK) Ltd



Zefa

AudioVisual

Compact disc and video *recorders lead the audio-visual revolution in the home. Rapid advances in laser technology and computerization mean that extremely sophisticated equipment can be mass produced and sold at an affordable price.*

WE ARE LIVING IN THE AGE OF information. The large amount of communication, as well as the sophistication of sound and picture reproduction, that can be called up by almost anyone, are all part of a world-wide audio-visual revolution.

Two of the most popular forms of storing and reproducing sound have been on records and tapes.

On the surface of a record, a fine groove spirals in from the edge of the disc to the centre. It is within this groove that sounds are stored as replicas, or an 'analogue', of the original sound waves.

To make a gramophone record, a master disc is first produced from a tape recording of the sounds made in the studio. A blank, lacquer-coated metal disc is spun on a turntable and a chisel-shaped cutter is lowered on to its surface.

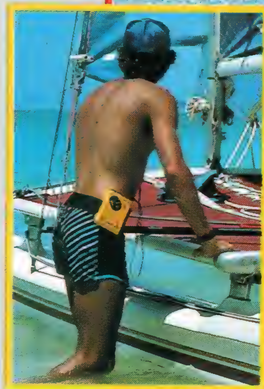
Sound signals from the tape make the cutter vibrate rapidly so that it cuts a wavy track through the lacquer as the disc rotates.

Plating and stamping

The master disc is plated with silver and nickel to form a master shell, which is then peeled from the lacquer. After further plating processes, a metal shell called a stamper is produced. Two different stampers, one for each side of the record, are placed in a record press. The final disc is made by squeezing hot pvc between the stampers and then trimming any excess plastic.

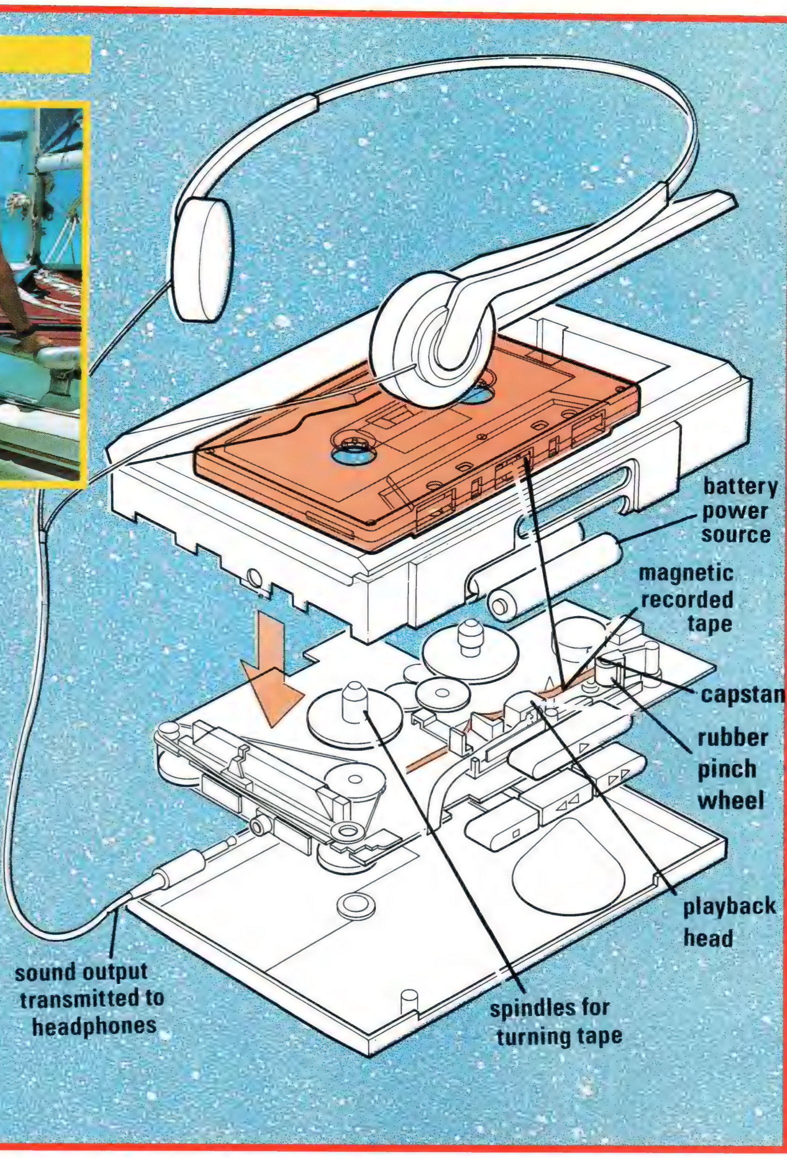
Back at home, the disc spins around on the record-player turntable at the same speed as it was recorded – 33, 45, or, rarely, 78 rpm (revolutions per minute). When the needle touches the surface, it slots into the winding groove and begins to vibrate as it traces out the pattern of waves. The tiny to-and-fro move-

PERSONAL STEREO



A portable cassette player can be taken anywhere – even under water, if it is the right model. The basic principles of a conventional cassette player apply, but in miniaturized form. The tape in the cassette is moved along by the capstan. As it passes the playback head, the signals imprinted on the tape are read by the head, amplified and then transmitted to the earphones. Some personal stereo machines can also be used for recording. They have an extra head for erasing used tape and may have a microphone.

Sony (UK) Ltd



Steve Latibeaudrere

ments of the needle are turned into electrical signals by the cartridge. These are then strengthened in the amplifier and fed to loudspeakers.

All on tape

Records give good-quality reproduction but are easily damaged. By comparison, tapes last much longer and can be played in a car or on a machine fastened to the waist.

A tape is basically a long ribbon made of plastic. But on the surface of the plastic, microscopic particles of iron oxide or chromium dioxide have been deposited. When these particles are exposed to magnetic forces, they rearrange themselves into invisible patterns.

To record, the microphone picks up sounds and changes them into electrical signals. These are amplified and fed to the recording head of the tape recorder. The head, a kind of electromagnet, changes the signals into a varying magnetic field. As the tape moves past the head, it is magnetized with a pattern that corresponds to variations in the original sound waves. This magnetic recording is automatically erased if the tape is used to record other sounds at a later date.

Usually, the same head is used for recording and replaying the tape. On replay, the magnetic pattern in the tape produces a varying electrical signal in the head, which, after amplification, is fed to the loudspeaker to be turned into sound.

Most tape players today are of the cassette variety, running off tape that is approximately 4 mm wide. Open-reel machines, once common in the home are now found mostly in recording studios. Some studio tape machines can record up to 32 separate sound tracks side by side on a wide tape.

Sony (UK) Ltd

The talking note pad *is a very small form of tape recorder. It takes a micro cassette, but it is not suitable for high quality recording.*

Better by numbers

With their shining silvery surfaces, compact discs, or CDs, provide almost fault-free sound reproduction. This is because they store sounds, not magnetically or by wavy grooves, but in the form of numbers, which are digitally translated into microscopic pits burned into the surface of a disc by a laser beam.

To make a compact disc, the signals from a studio microphone are first changed into numbers (digitized). These numbers are then translated into instructions to the laser beam, which etches the surface of the blank rotating master disc accordingly.

As in ordinary disc manufacture, the master disc is used to make stampers that press out the CDs.

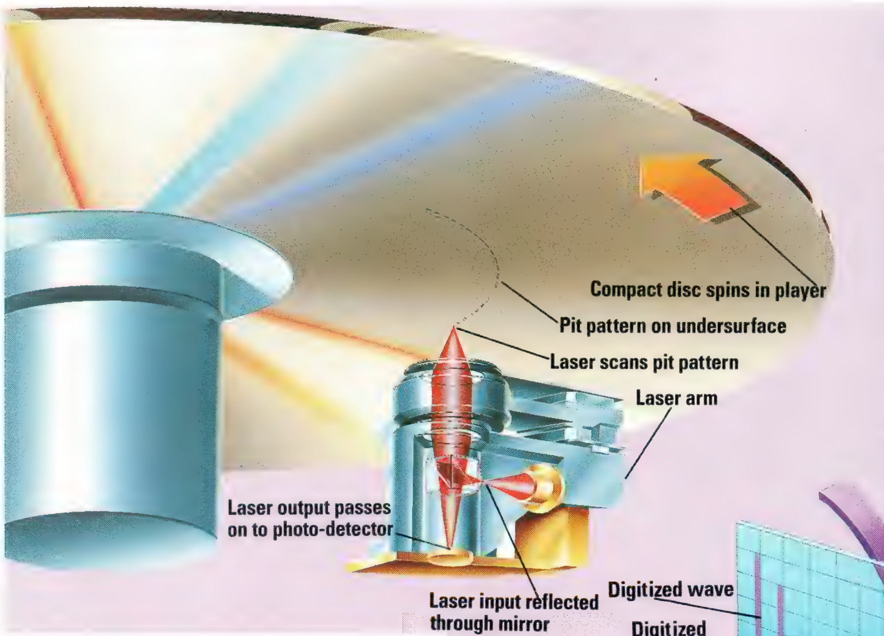
In the player, the compact disc spins around over a laser beam.

Just amazing!

SOUND MONEY

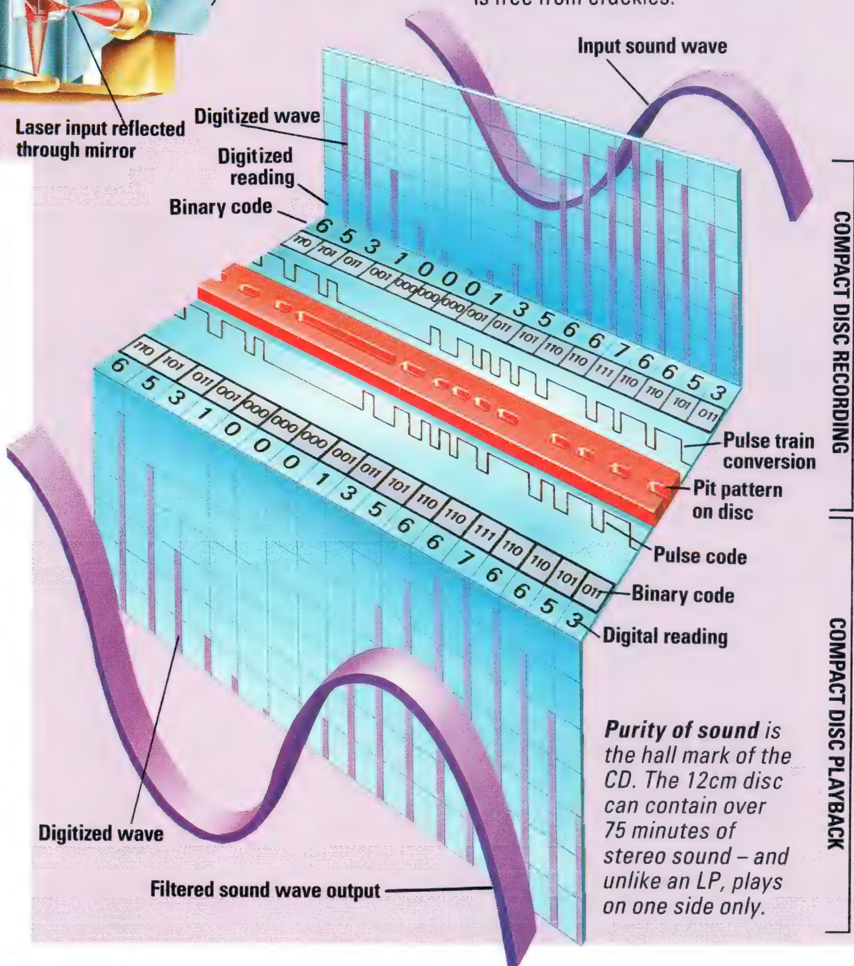
IN AMERICA, A NEW STYLE CREDIT CARD WILL BUY YOU MORE THAN MONEY AT AN AUTOMATIC CASH TILL – IT ACTUALLY PLAYS YOU MUSIC WHILE YOU WAIT.

Paul Raymonde



HOW A CD WORKS

As the disc spins in a CD player, a laser beam scans its partly pitted surface. The beam is reflected by a prism or semi-silvered mirror on to the disc. When reflected straight back from a flat part of the disc, the beam passes through to the photo-detector. This changes the flashes of reflected laser light into electrical pulses, which are used to reconstruct the original sound signals. Dust or scratches on a CD have little effect on the amount of light reflected from the surface, so the sound reproduction is free from crackles.



***Purity of sound** is the hall mark of the CD. The 12cm disc can contain over 75 minutes of stereo sound – and unlike an LP, plays on one side only.*

Kee Scott Associates

When the beam hits a flat part of the disc, it is reflected on to a device called a photocell, which then gives out a small electrical current. But when the beam strikes a pit on the disc, it is scattered and no current flows from the photocell. The resulting digital signals are changed back into their original, analogue form, amplified and used to produce sounds in the loudspeakers.

Digital audio tape (DAT) is the digital equivalent of ordinary recording tape. Here, the sound is recorded and played back digitally with high quality tape, which records the signals as invisible magnetic patterns. However, digital tapes can only be used on a 'dedicated' (specially designed) machine.

The video invasion

If there has been a revolution in the hi-fi industry, it is nothing compared to what has taken place in the world of video. Video recorders are so popular that around three quarters of homes in Britain now have one. And the video camera has revolutionized security as well as entering the leisure market.

***As video recorders** become sleeker, they also include more features. Some record stereo sound, and the remote control can even be used to set the programme timer.*

Philips

There are video discs, which work on the same principle as CDs, although the picture signals are analogue, but for the present, magnetic tape continues to rule the market. The video cassette recorder (VCR) is simply a compact version of the video tape recorder that has been used in television studios for many years. One lead connects it to the TV aerial and another, to the TV set. This means broadcast signals must pass through the VCR before reaching the television.

With its own built-in TV tuner and receiver, the VCR can record programmes without the TV set being switched on. It can also record from one channel, while the TV plays a different channel.

The process of video recording is

INTERACTIVE VIDEO

Steven Hunt/Image Bank

A link between videos and computers provides a valuable educational aid. An optical laser disc presents the user with a programme containing a list of options, such as countries. An option is selected, perhaps China, and the computer runs a video on it. Now CDIs (compact disc interactive), where a CD provides audio and visual information, are fast developing for the domestic market.

basically the same as tape recording. Light and sound from the scene are picked up by the camera and an attached microphone and turned into a stream of electrical signals. These signals are converted to magnetic variations in the recorder and are stored on the tape.

Vision signals contain frequencies much higher than those of sound signals. In order to record such signals, the speed of the tape relative to the recording head must be very high. In early video recorders, the tape moved at the speed of a sports car. But huge reels of tape were needed, and it was liable to stretch or break when suddenly stopped. In modern VCRs, a rapidly rotating head records the vision signals in diagonal strips across the tape, which moves past at slow speed. Thus a high tape-to-head speed is obtained without the tape itself having to move fast.

Some video recordings are not as clear as the original programme. This is because standard tape can accommodate a 'band width' of only half the frequencies transmitted.

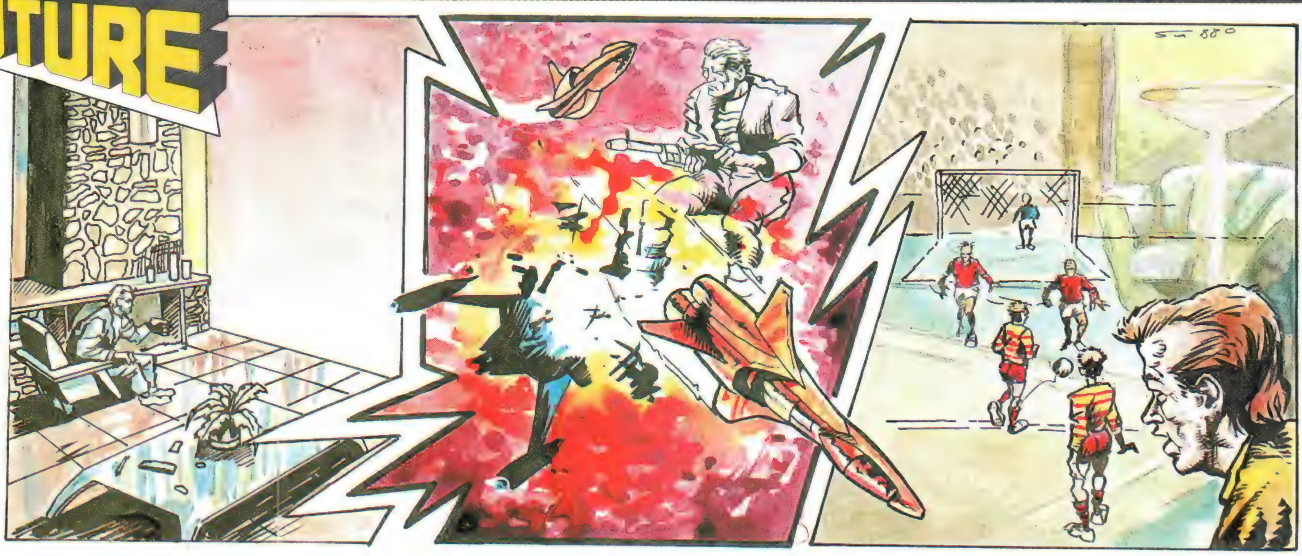
Super VHS or Hi8 tape can take on much higher frequencies – even higher than a normal TV set – thanks to the smaller magnetic particles coating it. However, you need a special machine to use them.

Hitachi (UK) Ltd

***The video camera** has revolutionized home movie-making. Most cameras feature a microphone, an adjustable lens, automatic exposure and limited editing facilities.*

INTO THE FUTURE

THE BEST SEAT IN THE HOUSE



...n Burrows

▲ Interactive video combined with 3-D viewing on a grand scale could bring any event – real or imagined – into the sitting room of the future.

▲ At the touch of a switch, the viewer could feel himself projected into the action of a movie and experience the sensation of actually participating in the scene.

▲ Or by simply choosing his own camera angles, he could find himself viewing his favourite football team from the 'best seats' in the stadium.

FRAUD AND FORGERY

MGM/Kobal Collection

- COMPUTER HACKERS
- FAKE BANKNOTES
- HIGH-TECH TESTS

A SCHOOLBOY COMPUTER whizzkid penetrates the military computers controlling the US missile system and convinces experts there that a World War is about to start.

Fortunately, it all takes place in a movie – *War Games* (above) released in the USA in 1984 and in the UK in 1986. But such fantasies about 'hacking' – as this activity is called – have come close to the truth. In 1985, seven teenagers were found guilty of hacking their way into computer systems controlled by the Pentagon, the US Military High Command headquarters, in Washington.

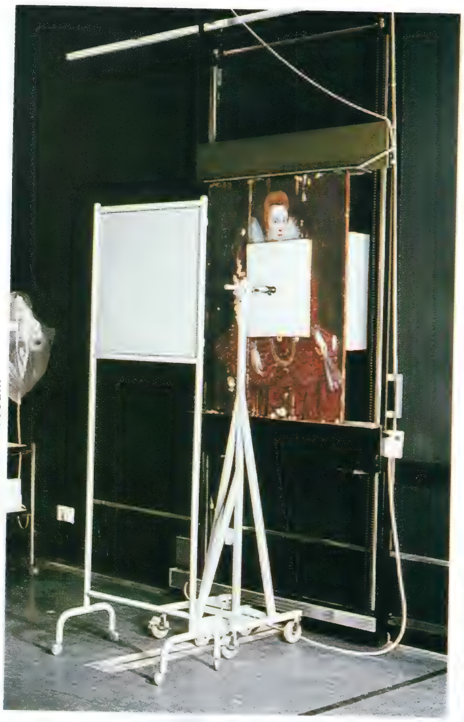
By the time the FBI (Federal Bureau of Investigation) caught up with them, the hackers had access to information that would allow them to alter the position of American weather satellites.

Many computers protect their stored information by insisting that

De La Rue

Oliver Boitet/Gamma/Frank Spooner Pictures

***The graphic arts camera** is used by more than 85 per cent of the world's banknote counterfeiters. The boxes (inset) contain seized counterfeit French currency with a face value of 70 million francs.*



Hamilton Kerr Institute/Fitzwilliam Museum

***Suspect paintings** are examined using an X-ray source behind the painting, while a photographic plate is pressed on to the paint. When the plate is developed, fresh paint and any alterations can be spotted.*

a password is typed into the machine before access is allowed. Commercial computer networks, such as British Telecom's Prestel, have elaborate protection devices. But even these have fallen before the determined hacker.

While hackers are becoming a serious menace to commercial companies who keep all their records on computer, far more dangerous are employees who use their knowledge of the company's passwords and accounting methods to syphon off cash for themselves.

Computer fraud is merely the more glamorous form of a criminal activity that has been around as long as clever and skilled people have been able to simulate anything valuable, from passports to paintings and perfumes.

Spotting the fake

The most basic weapon in detecting fraud in a document is a sharp eye. Usually an experienced forensic scientist will first look for obvious clues, and then seek the aid of instruments, starting with a low-power microscope.

Most paper is manufactured with a particular watermark – an almost invisible, transparent symbol which can be seen when the paper is held up to the light. The mark is made when the paper is manufactured. It can be imitated using a wooden stamp and olive oil. However, the false imprint has sharper edges than the original, and can be detected using a microscope.

Another way of checking a suspected fraud, such as a faked signature, is by viewing it under ultraviolet light. If the original signature has been removed, the impression it left will show up under the light.

For further investigation, the object, or a small portion of it, is subjected to chemical analysis.

Gamma ray dating

To determine its true age, a sample of an object may be made radioactive. The rate and intensity of gamma rays it emits can then be used to accurately calculate the age.

The disadvantage of this method is that it leaves the sample highly radioactive, and so it must be kept well shielded afterwards to avoid dangerous radiation from it.

Ancient artefacts able to withstand great heat, such as pottery, can be distinguished from fake lookalikes by a method known as thermoluminescence. When the clay is fired to about 600°C, it emits energy in the form of light, which can then be measured to calculate the date of origin of the clay.

Printing money

Banknotes have always attracted the attention of counterfeiters, and modern technology is making it much easier to produce high-quality colour copies of printed material. However, the companies responsible for designing and printing banknotes have introduced various measures to make realistic copies difficult to produce and to make forgeries easy to detect.

Modern banknotes bear intricate designs containing numerous fine lines, originally made in metal by a master engraver. Such fine detail is extremely difficult to copy, even

Paul Raymonde

using the best reproduction equipment. Other security measures include the use of intaglio (sunken) printing to give the notes a characteristic 'feel', special threads incorporated in the paper, the use of watermarks, and the individual number of the notes. Some notes are printed with a fluorescent metallic ink, the appearance of which is impossible to reproduce by normal copying techniques.

Some of the most attractive forgeries have been made by painters accomplished enough to imitate a great master. Their motives are varied, from frustration to resentment against the established art world. If their art does not give them away, their materials do. Paints, pigments and techniques have changed greatly over the years, and sophisticated chemical detection means it is now extremely difficult to cheat the forensic scientist.

THE TURIN SHROUD

The Holy Shroud of Turin – for centuries thought to have covered Christ's body after the Crucifixion – has been revealed as a fake. British scientists, using radio-carbon dating techniques, have shown that the shroud was probably made in the mid-1300s.

Believers in the shroud's link with Christ thought that heat generated by the Resurrection had somehow scorched an image of Christ's body into the material. However, doubts about its authenticity are not new.

As long ago as 1389, a French bishop declared that the image had been 'cunningly depicted' by an artist in order to convince others that it was Christ's shroud. The artist was even said to have confessed to his crime. Nevertheless, many clung to their belief of the shroud's authenticity and, even now, many will probably choose to ignore what the scientists have to say.

Frank Spooner Pictures

COMPUTER-AGE POLICING

- COMPUTER DETECTING
- TRAFFIC CONTROL
- INTERPOL

POLICE SEARCHING FOR THE killer of the Scottish schoolgirl, Susan Maxwell, amassed over 75,000 statements from potential witnesses. The paperwork alone weighed over seven tonnes and architects had to be called in to check whether the floors of the police station were strong enough to support the weight.

Faced with such a mountain of paper, detectives had the greatest difficulty in searching for any kind of common thread, or locating facts when they were needed. When Susan's murder was followed by two further killings, which bore the hallmark of the same person, the police decided that only HOLMES could crack this particular case.

***Motorway traffic** is monitored by computers, enabling the police to minimize delays caused by accidents and get help quickly to injured victims. Their task becomes more and more vital, as traffic volume increases.*

Master detective

HOLMES is not the mythical detective created by Conan Doyle but a computer system – the Home Office Large Major Enquiry System. The one gigabyte capacity (100 million words) of its computer is sufficient to store and digest the vast number of witness statements generated by a major crime enquiry and to assist officers in tracing common themes and patterns.

One of its unique features is free text retrieval. Thus, if a witness mentions the fact that he saw a man in a leather jacket near the scene of crime, it is possible at the touch of a button to call up any other statements, from among the thousands collected during the course of enquiries, that also mention men in leather jackets. Another aspect of the system is the exceptional reporting feature that alerts the operator when a witness mentions a person who has been linked to the crime by another witness.

Police investigating the Yorkshire Ripper murders could have made good use of this feature when different officers managed to interview the Ripper, Peter Sutcliffe, on nine separate occasions without

***Radio controlled** cars enable police to be on the spot whenever trouble arises – their radios allow them instant access to the Police National Computer.*

Metropolitan Police

the common pattern being noticed. HOLMES is expensive, and is used for major crime. More routine policing relies on another computerized communication system – the Police National Computer (PNC).

Information store

The PNC is housed in a special high security building at Hendon, near London, and currently consists of three central processing computers, with a capacity of over 12 gigabytes – more than 1,000 million words. There are plans to increase this number substantially.

The information stored on PNC includes:

- records of 36 million vehicles and their owners
- stolen and suspect vehicles
- criminals' names and their known aliases
- descriptions of criminals and their fingerprints
- names of disqualified drivers
- wanted or missing persons.

Police in the regional forces keep in touch with PNC via some 1,300 computer terminals in local stations, which flash information back on a video screen. These facilities are backed up by nearly 200 dataprinters, which provide a more permanent written record of any information requested. Officers on the beat carry personal radios that give them access to PNC's memory.

Instant check

The most frequent use of PNC by officers on the beat is for checking the owners of suspect vehicles. These amount to over 20 million in a year, or around two thirds of all requests for information.

Rex Features

***Interpol** provides police throughout the world with a computer network that helps track down criminals, such as international gun-runners. In 1987, the Eksund, an IRA arms ship on course from Libya to Ireland, was seized off the coast of France from information fed in by the British police.*

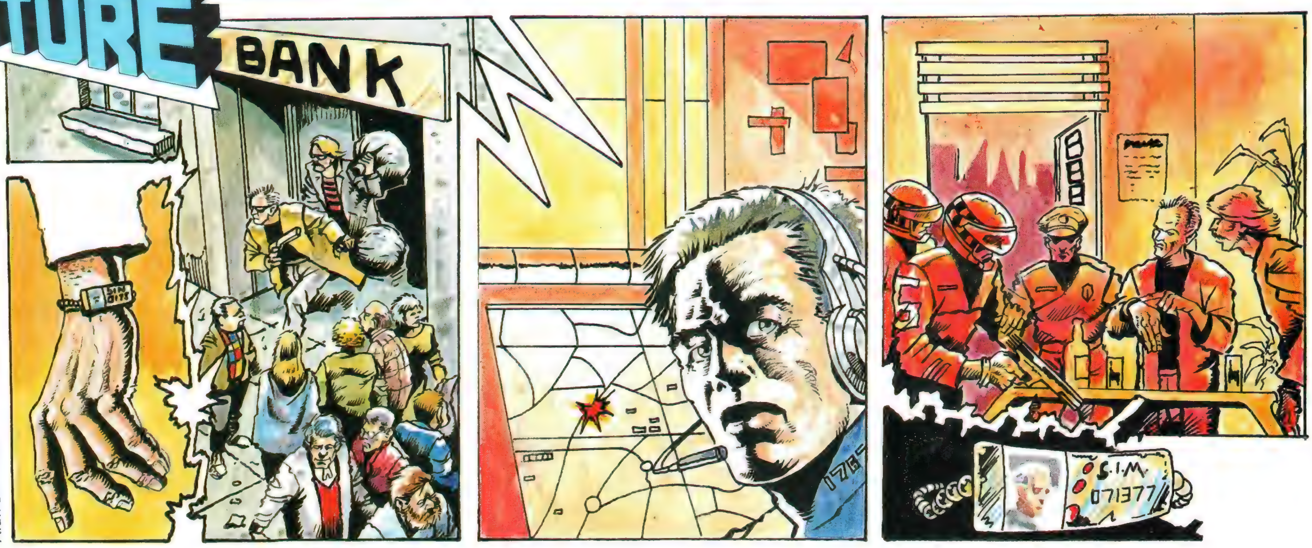
Other major uses for the system are checking on the identity of suspects and possible missing persons. Each of these services are used about nine million times a year. Electronic links are gradually being established between PNC and various regional memory banks or 'databases'. This means that if an officer requires more information about a suspect, he or she can be directed elsewhere on the electronic network.

International policing

For policing worldwide, an international computer link is provided by Interpol. Interpol helps police to gather information as and when requested. However, a new 'gathering and sharing' agency, Europol, is now being set up to provide police throughout Europe with a readily available bank of information on computer.

INTO THE FUTURE

KEEPING TABS ON CRIME



Alan Burrows

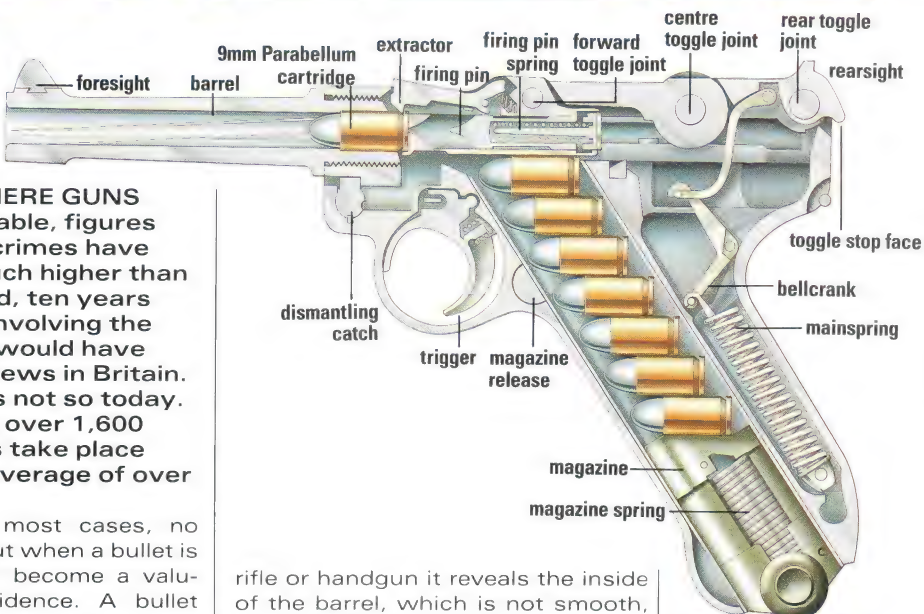
▲ The time may come when all criminals have their own computerized identity bracelets, which will allow the police to monitor their every movement.

▲ As soon as the alarm is raised when a crime is committed, the police will be able to isolate all the identity bracelets in the area and check criminal records.

▲ Any suspected criminals can very easily be tracked down – no matter where they are. The police can then pick them up and bring them in for interrogation.

GUNS AND BALLISTICS

Gamma/Frank Spooner Pictures



A Luger ready for firing – its firing pin cocked. The extractor, forced up by the chambered cartridge, shows the gun is loaded. The spent cartridge is ejected as the firing pin retracts.

IN THE USA, WHERE GUNS are readily available, figures for gun-related crimes have always been much higher than in Europe. Indeed, ten years ago, any crime involving the use of firearms would have made headline news in Britain. Unhappily, this is not so today. In London alone, over 1,600 armed robberies take place each year – an average of over four each day.

Fortunately, in most cases, no weapon is fired. But when a bullet is discharged, it can become a valuable piece of evidence. A bullet carries on it marks as unique to the weapon which fired it as the human fingerprint.

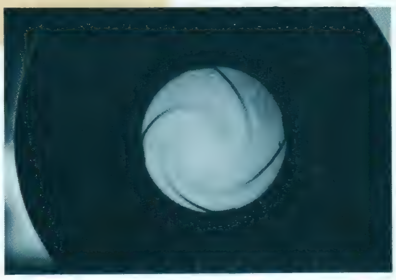
To determine whether a bullet came from a particular gun, police experts in ballistics (the science of how projectiles travel) use a special instrument called a helixometer. This consists of a fine tube with a light and magnifying lens at one end. When placed in the barrel of a rifle or handgun it reveals the inside of the barrel, which is not smooth, but cut with a series of spiral grooves known as rifling.

A bullet will travel further and straighter if it is spinning. The spirals in the barrel of the gun are designed to impart twist to a bullet in order to achieve that spinning effect. The raised parts of the spirals, called lands, are separated from each other by grooves. The internal diameter of the barrel is known as

IDENTIFICATION MARKS

An undamaged *bullet can be examined by ballistics experts to compare the striations (marks) on it with the rifling on the inside of the gun barrel. When a bullet hits its target, it disintegrates in different ways, depending on whether it hits soft flesh or bone.*

In the ballistics laboratory, experts use three different types of microscope. A comparison microscope is used to compare two bullets for corresponding marks, a fibre optic bore microscope for viewing rifling details, and a measuring microscope for calculating rifling characteristics on fired bullets.



Hicks Photographic Services

the calibre and determines the size of ammunition fired.

Bullets are always slightly larger than the calibre of the gun that fires them. This ensures that, as the bullet travels down the barrel, the fit is tight and none of the power of the propellant gas behind the bullet is lost through leakage.

As the rotating bullet is forced down the barrel, the rifling scars the bullet in characteristic ways. So characteristic are these marks, or striations, that an expert can immediately deduce what type of gun fired which bullet.

The individuality of guns does not end with types of weapon. The machine tools used in the factories that introduce the rifling on gun barrels are sharpened frequently. Every time this is done, it introduces a different pattern of microscopic marks in the barrel of a given weapon and these are impressed on every bullet fired from it.

Police can, therefore, prove whether a particular gun fired a bullet recovered from the scene of a crime by taking the gun and firing a second bullet, which can be compared with the first. The striations on the two bullets can then be compared using a comparison microscope. If the marks match perfectly, both bullets came from the same weapon.

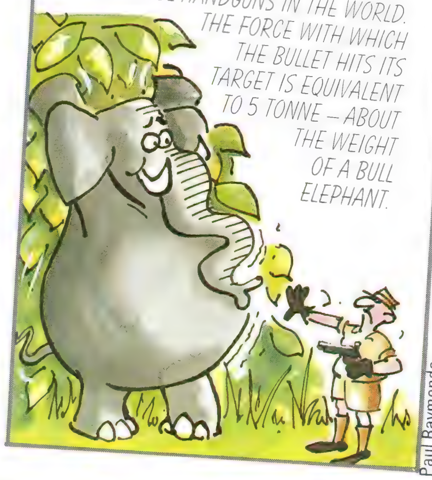
There is one kind of weapon that has an unrifled barrel – the smooth-bored shotgun. Criminals sometimes saw off the barrel and cut down the wooden handle, or 'stock', to produce a sawn-off shotgun — easily concealed and deadly.

Instead of bullets, shotguns fire a mass of tiny lead pellets. Over 2,000 of these are packed into each shotgun cartridge. Although the pellets do not reveal which gun they come from, the empty cartridge case carries an important clue. Its brass base bears the mark of the gun's firing pin. Each gun leaves a slightly different mark on its cartridges, so it is easy to determine whether or not a particular gun fired a particular cartridge.

Just amazing!

MAKE MY DAY

THE MAGNUM .44 IS ONE OF THE MOST POWERFUL HANDGUNS IN THE WORLD. THE FORCE WITH WHICH THE BULLET HITS ITS TARGET IS EQUIVALENT TO 5 TONNE – ABOUT THE WEIGHT OF A BULL ELEPHANT.



Paul Raymonde

CRIMINALS' CACHE

Guns *now in police possession reveal the criminal's preference for sawn-off shotguns as effective short-range weapons.*

Metropolitan Police

UNSCRAMBLING JAMS TRACK SYSTEMS FLOATING TRAINS

GETTING ABOUT TOWN

Hutchison Library

Zefa

Rush hour in New York can be a rough ride for commuters by car. Public transport can move large numbers of people more efficiently. The Sudanese train (inset) demonstrates that just over 500 passenger cars are not enough to provide an efficient railway service.

MILLIONS LIVE IN CITIES ALL over the world and millions more pour into them every day. The congestion and pollution that result put traffic and public transport problems high on the list of a city's priorities.

One way of discouraging heavy traffic is to turn busy parts of a city, such as shopping centres, into pedestrian-only precincts.

Another way to lessen pollution from exhaust fumes is to encourage bicycles by providing ample bicycle-only lanes. Amsterdam has long given precedence to pedal power, but in less affluent Beijing – the capital of the most populous country, China – bicycles are all that the majority can afford, and the odd car is usually completely swamped in huge bicycle jams.

No matter how many more roads are built to cope with increasing traffic, it has a knack of multiplying to fill the available space. The answer lies, therefore, in better traffic management. This includes highly sophisticated traffic control systems, such as UTC – Urban Traffic Control – which uses the latest microchip technology direct from a central computer.

Computerized traffic

Programs, such as TRANSYT and SCOOP, vary traffic signal rotation according to the flow of traffic. This is monitored by vehicle-detector induction loops embedded under the road near intersections. Journey time has been reduced by nearly 20 per cent, and fuel consumption about 15 per cent because of them.

Special lanes for buses, sometimes in both directions in the centre of a major urban throughway, as in Washington DC, allow many more people to travel much faster than in individual motor cars. Not

***A computerized map,** such as Digiplan in Lyons, France, automatically shows the best route for individual passengers to any destination within the city. A very simple route planner is available in a number of London underground stations.*

Zefa

only are buses monitored along special bus lanes, again, by induction detector loops under the road, but many are equipped with two-way radio. This keeps both driver and the central control in touch with each other about existing conditions on the road, so that the best route and the frequency of buses can be monitored.

Inductive loops can also be used to drive the bus. In Sweden, they steer the bus accurately to a bus stop. When the bus approaches the loop, the driver switches to auto-control and the bus aligns and halts perfectly.

Specially allocated lanes for public transport are difficult to maintain, but vehicles on a permanent track, especially if it is banked off, always have right of way. This is the great advantage of tramways and trolleybuses. Many cities are returning to modern versions of the tram. The cost of re-introducing trams is much less than for excavating new tunnels for an underground system.

Making tracks

Trams and trolleybuses require overhead cables to supply the power, and tracks for wheel guidance. Tracks can be elevated, partly sunk or tunnelled. The overhead cables are not always necessary as some trams or trolleybuses carry batteries which can be charged from the cables earlier in the journey to provide power in areas where cables cannot be accommodated, as in residential areas. Alternatively, the trolleybus may be fitted with a supplementary diesel traction engine.

A type of diode, called a thyristor, regulates the speed by interrupting the power. This is known as chopping. The energy produced by braking is returned to the main power supply, making an energy saving of up to 40 per cent.

A cross between a bus and a train is the German O-bahn system. Where necessary, the bus is guided along special tracks — sometimes

A fully automated *shuttle service, the Docklands Light Railway, is London's latest addition to public transport. It runs completely on overhead tracks.*

UNDERGROUND HQ

Computers help run the world's largest underground system in London, as communication is vital to ensure a smoothly run network. Up-to-the-minute information, relayed instantly between stations down the line, helps to monitor the frequency of the trains and keep waiting passengers informed.

Barry Lewis/Network

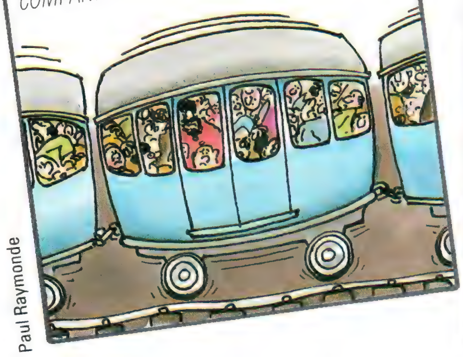
Hutchison Library

Reflecting luxury *of a bygone era, the Moscow underground carries over 2,500 million passengers each year.*

Just amazing!

RUSSIAN ROULETTE

RIDING AROUND ON THE MOSCOW UNDERGROUND IS NOT FOR THE CLAUSTROPHOBIC. EVERY DAY, SEVEN MILLION PASSENGERS KEEP EACH OTHER COMPANY.



Paul Raymonde

TUBE DISASTER

Millions travel on underground trains daily and accidents are rare. Safety depends greatly on stringent cleaning and good communications at all levels. A cigarette butt thrown on an escalator at Kings Cross station, London, set fire in November 1987 to uncleared grease and rubbish below. As a result of the fire, cigarette smoking was banned in all stations and 104 new safety procedures were instituted.

Gamma/Frank Spooner Pictures

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***The Bay Area Rapid Transit** of San Francisco (BART) runs underwater for 6 km along the bay and is unstaffed. The entire system is operated by just two supervisors in a central control room and by computers at each of the stations en route.*

J. Allan Cash

***A funicular** riding high is one way of getting about in a steeply terraced town. A form of cable car, funiculars can negotiate gradients very efficiently. The cars are merely carriages, as the cables they run on are pulled by a stationary engine.*

automatically — but otherwise, is left to be driven freely by the driver.

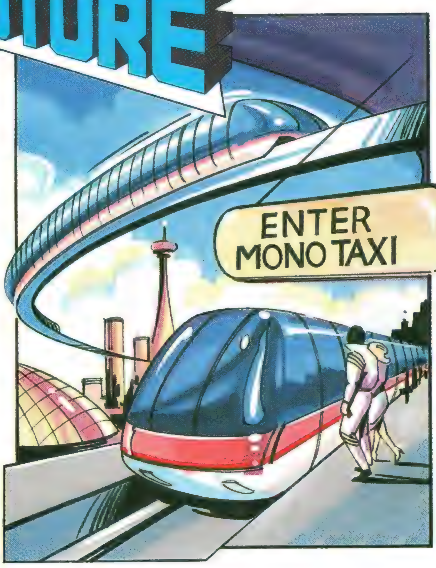
Tracks running through tunnels under a busy city provide one of the heaviest used networks of urban public transport. Free from overhead traffic jams, each underground train has unimpeded right of way within its own tunnel. In London, where the first electric underground train ran in 1890, more than two million people travel on it each day.

Underground trains differ in carriage, shape and style in different cities, but the basic principles of locomotion are the same. Electric power supplied along the tracks is picked up by the driving or traction carriages at the front and the rear of the trains.

The power is taken either directly from the National Grid or from the transport organization's own generating stations. Varying degrees of automation are available — from automatic door closing systems and trains without guards, to fully

INTO THE FUTURE

TRAVELLING TOMORROW



▲ *Passengers on public monorails could have individual free carriages detached to run as taxis to fixed destinations along the track.*

▲ *Electrically driven cars would be re-charged at self-service 'filling' stations. Credit cards could be used to operate the terminals.*

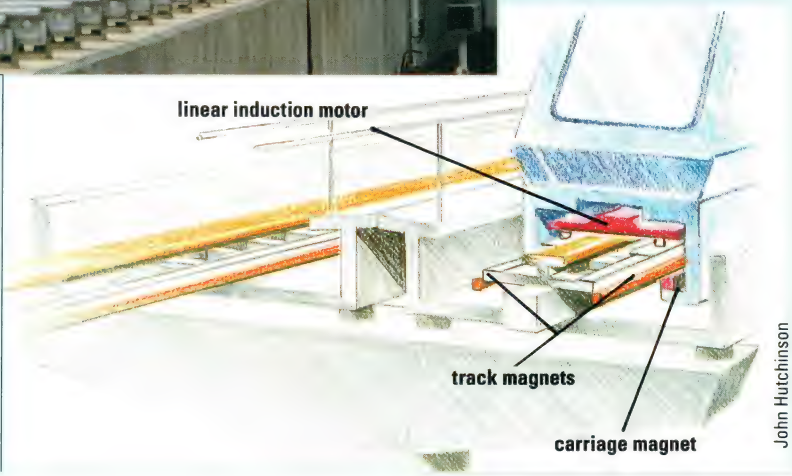
Joe Lawrence

▲ *Moving walkways used for long distance strolls would have three lane tracks at different speeds to avoid accidents.*

Gamma/Frank Spooner Pictures

The maglev that runs at Birmingham airport (left) operates on the principle of unlike poles attracting each other. This is known as EMS, or electromagnetic suspension. Permanent magnets in the track face downwards, while electromagnets under the vehicle bracket the tracks and face upwards. When the electromagnets are energized, they are attracted towards the track magnets. Special control systems keep train and track 15mm apart, regardless of the load carried.

The Japanese run a maglev – a train kept above the tracks by magnetic levitation – on the principle that like magnetic poles repel each other. This is known as EDS, or electrodynamic suspension. Permanent magnets on the underside of the carriage generate a current as they pass over coils in the track. The current magnetizes the core of the coil to the same polarity as the vehicle magnets, and the resulting repulsive force levitates the vehicle. Another set of magnets and coils generates the electricity as the train moves along. Thus, only a part of the track is electrified at a time.



John Hutchinson

computerized trains which run without drivers.

But underground systems are horrendously expensive to construct. That is why many cities opt to supplement their existing public transport network with more overland track systems, such as the funicular or cable car. It is used chiefly in hilly areas and towns with steep inclines, and is cheaper to build than roads or railways.

But cable cars can carry only a limited number of passengers as the cable track can transport only two cars at a time. Usually, cable cars are run in tandem in opposite directions – one being pulled up by the other travelling down. The track is just like a railway track except for the cable running down the centre.

Poles apart

Of all various forms of public transport a city can provide, the most innovative is the train that virtually 'flies' over the track by magnetic levitation – the maglev. Because it has no moving parts, there is no wear and tear from friction and the ride is smooth and silent.

Maglev becomes increasingly more efficient with the advances made in superconductors. At an extremely low temperature, a superconductor provides almost no resistance to an electric current passing through it. This allows the current to flow almost permanently, with very little wastage. Because of superconductors, very strong electromagnets in the rail and the train can be made to attract or repel each other with such force that a gap of approximately 15mm can separate the train from the track.

Maglevs, at present, are used only for short journeys, but they can travel at up to 504 km/h.

Aviation Picture Library

***Helicopter travel** is increasing in popularity as roads become more congested. In a densely populated city such as London, helicopters are widely used by the police to survey traffic conditions or to help with crowd control.*

EFFLUENT DISPOSAL

SEWER NETWORKS

CLEANING UP

THE WASTE CYCLE

YOU ARE THIRSTY. YOUR hands are dirty. You turn the tap on, out comes water – however much you use, there is always more whenever you want it. And that's a modern-day miracle, only to be seen in the developed world.

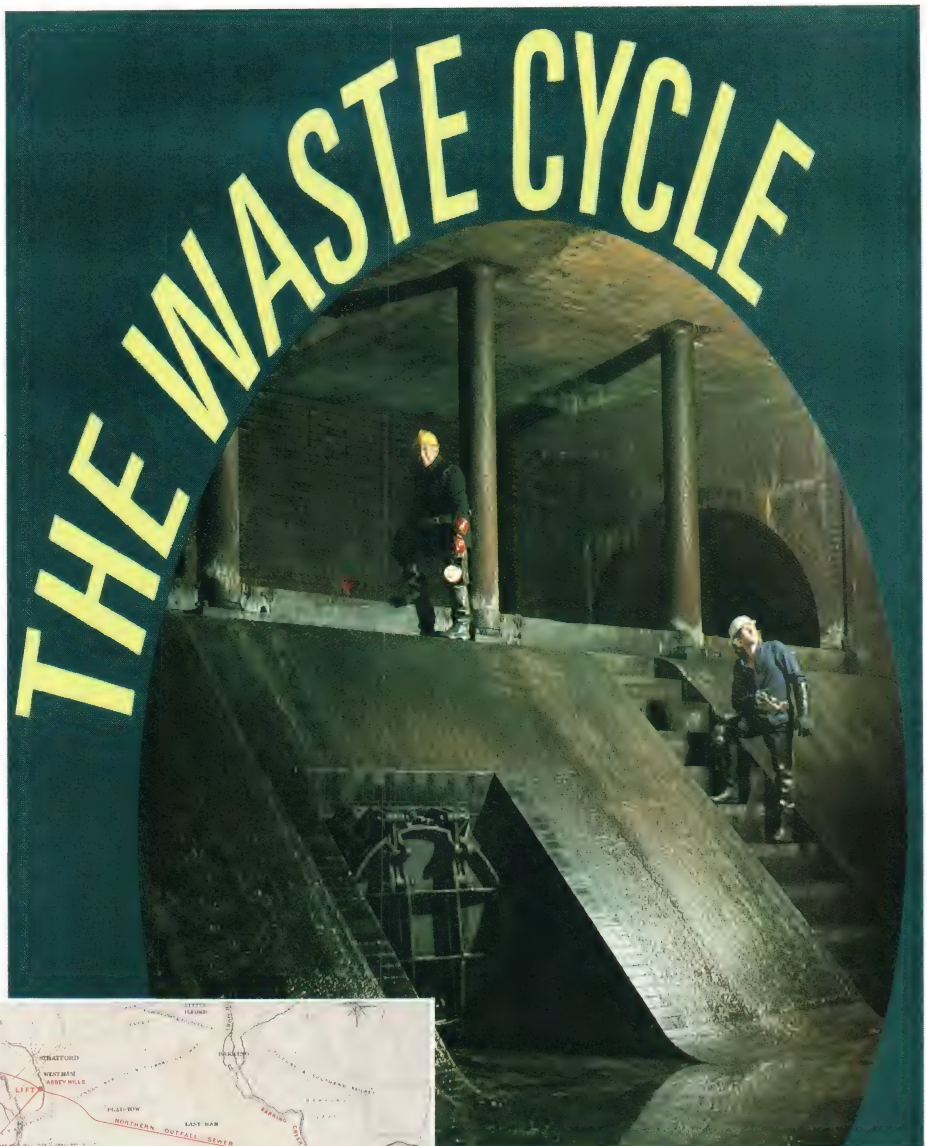
The average Londoner uses over 150 litres of water a day, washing, drinking and cooking. But once used, the waste water has to be collected, cleaned and returned to the river or sea in a state fit to be drunk so that the cycle can start over again.

Sewage works

The waste water leaves each house in an underground sewer, which joins larger and larger ones until they all meet the main trunk sewers. The largest sewers are the size of underground railway tunnels and carry huge quantities of rainwater. Having been in place for more than 100 years, many of London's sewers are in poor condition, and the city faces a crisis as more and more collapse under the weight of traffic on the streets above.

At the sewage works, the first job is to remove rags, wood and floating objects which would otherwise damage the pumps and machinery. Raw sewage is passed through screens of metal bars spaced close together. These trap large objects which are then raked off. Those that can be broken down are torn into small pieces and mixed back into the sewage. The rest is burned or buried in landfill sites.

The next job is to remove as



Thames Water

***Working underground** in one of London's trunk sewers. These Victorian tunnels were not designed to cope with either the volume of 1990s sewage or the vibrations caused by heavy traffic, and are in severe need of replacement.*

Bridgeman Art Library/Guildhall Library London

***London's sewer network, 1865.** Nearly all the main trunk sewers running east to west are still in operation today.*

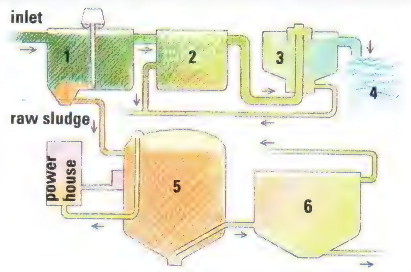
DOMESTIC CONSUMPTION

John Hutchinson

Thames Water

Grit is first removed from the raw sewage, which is then allowed to settle in the primary sedimentation tanks (1). In the aeration tanks (2), air is bubbled through the effluent to encourage bacteria digestion. The separated liquid settles (3), before being pumped into the river (4) as 96 per cent pure water.

Raw sludge is drawn off from the primary sedimentation tanks (1), and then digested in the primary sludge digestion tanks (5). The gas given off is then fed back into the power house. After four weeks, the sludge is passed to a secondary tank (6), before finally being dumped on land or at sea.



John Hutchinson

much of the solid matter as possible. The sewage is poured into large primary sedimentation tanks where the solids settle to the bottom. This crude sludge is swept into a hopper by electrically driven scrapers and pumped into a separate sludge digestion plant.

The remaining liquid – called primary effluent – is fed into the secondary treatment plant. Here, bacteria are added which feed on the waste matter in the sewage and digest it into water and gas. To function, the bacteria need a lot of oxygen. One way of providing this is by spraying the sewage on to a bed of gravel. As it passes through the gravel, it picks up oxygen from the air trapped between the particles. Another method passes compressed air into the effluent through special porous tiles called diffusers. These have small holes in them so that the air flows into the effluent as very small bubbles.

It takes about eight hours to digest most of the impurities. The sewage is then simply water that is clean enough to go back into the river or sea.

Sludge, gas and liquor

The crude sludge from the primary sedimentation tanks is pumped into the digestion tanks where bacteria are again used to digest the unpleasant and smelly material. In the process, sludge gas is given off containing methane which is burnt to power generators, thus producing all the electricity needed to power the sewage works.

After three or four weeks, all the sludge gas has been collected and the sludge is passed into open secondary digestion tanks. There, the thicker sludge settles to the bottom and the water – or liquor – remains at the top.

The thicker digested sludge can then be used on the land as a soil conditioner once the water has been removed. Any surplus is taken by ship and dumped out at sea, where it provides food for algae, the first link in the marine food chain.

This process of continually recycling all the side-products during purification ensures a degree of stability in the environment, since nothing is dumped as rubbish. Very few chemicals are added in the purification process, and yet most of the industrial wastes present in the sewage can be broken down by naturally occurring bacteria, without help from Man.

Sally & Richard Greenhill

***A shanty-town** in Manila, capital of the Philippines. With no true sanitation, the toilet-shacks overhang the river: 'flushing' involves dumping the raw sewage directly into the water below. A modern tower-block oversees the slum river.*

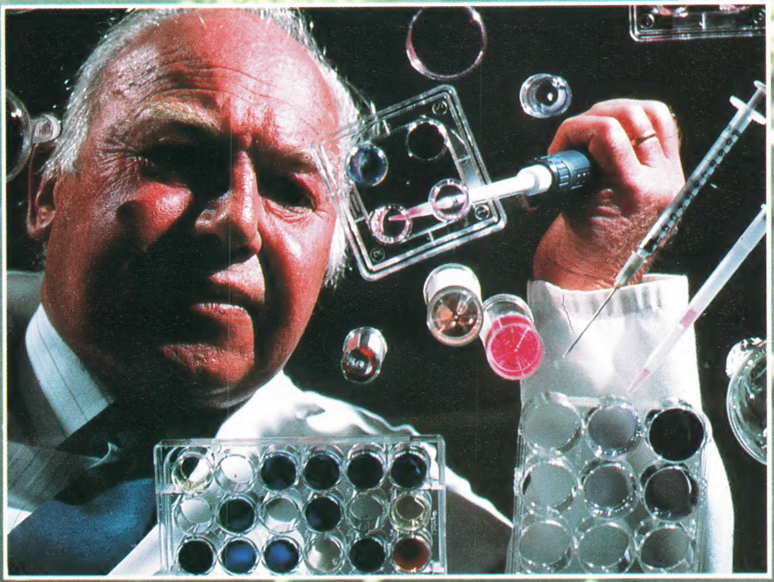
Just amazing!

DOWN THE DRAIN

IN LONDON, OVER 3 BILLION LITRES OF SEWAGE ARE GENERATED EVERY DAY. THAT'S AROUND 365 LITRES FOR EVERY MAN, WOMAN AND CHILD LIVING IN THE CITY.

XEROXING LIFE
FROZEN FUTURES
PLASTIC BODIES

CLONE ZONES


Topham

Scientists can reproduce life artificially by cloning. Donor tissue is injected into an unfertilized egg whose nucleus has been removed. Reproduction is achieved without male cells.

FLASHES OF LIGHTNING AND mad scientists cackling with evil glee may be the stuff of movies, but human and animal embryos are now being fertilized and modified in laboratories and operating theatres all over the world.

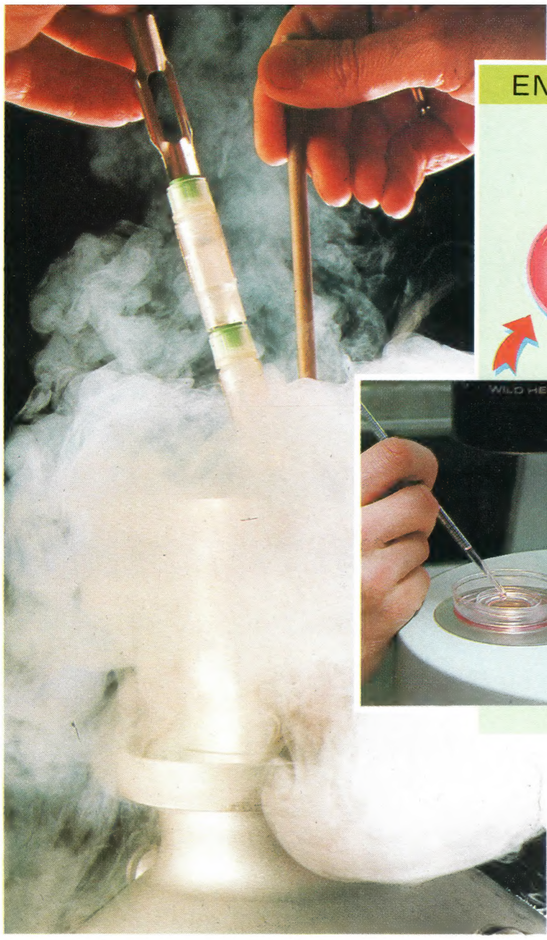
A chicken was the first warm-blooded creature to be developed fully in the laboratory. It was part of an experiment to manipulate livestock genes by injecting foreign DNA into single-cell embryos. The injected cells are nurtured in a solution of egg-white and salt at controlled temperatures inside a series of empty eggshells. Because chickens have thousands of offspring, it could be possible to create a strain of 'superchickens', starting with genetically-engineered birds, who would then go on to produce generations of offspring naturally. All these offspring would then pass on their 'improved' genetic information to their descendants.

Genetic engineering

Men have been experimenting with animals for centuries, trying to produce superior livestock. Artificial insemination is used to improve

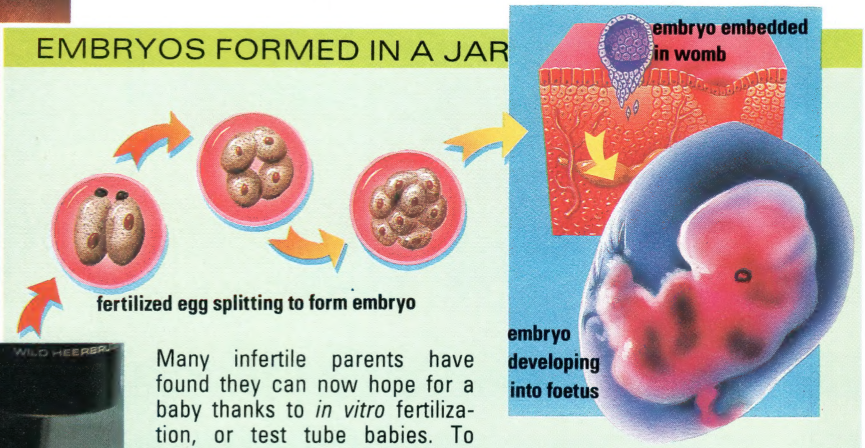

Derek Bromhall

***Identical genetically** and physically, cloned frogs are made from an unfertilized egg and donor tissue taken from a tadpole's intestine.*



Dan Esgro/Gamma/Frank Spooner Pictures Inset: Martin Dohrn/IVF Unit, Cromwell Hospital/SPL

EMBRYOS FORMED IN A JAR



Chris Lyon

Many infertile parents have found they can now hope for a baby thanks to *in vitro* fertilization, or test tube babies. To achieve this, the surgeon removes an egg from the woman's body and fertilizes it with the man's sperm in the laboratory (left). The fertilized egg then subdivides (above). At about this stage, the surgeon introduces the budding embryo into the lining of the woman's uterus (top right). Here, it will continue to develop into a healthy foetus (above). Sometimes, it is necessary to freeze the embryo until the woman's uterus is ready to receive it. At the right time, the embryo is thawed and then inserted into the uterus.

Sperm banks store frozen sperm *from donors – some even specialize in genius donors. The sperm is used for artificial insemination, and new babies can be made without the parents ever meeting.*

herds and flocks with sperm from champion stud animals. Embryo-transplanting enables breeders to obtain first-class stock without buying enormously expensive adult animals.

Cattlemen have introduced high-yielding, disease-resistant cattle from the USA to Africa, by taking large numbers of fertilized eggs and implanting them in the wombs of rabbits. The cattle embryos can survive in the rabbits' wombs for up to eight days. It takes no longer than a couple of days to fly the rabbits to Africa and the cattle station. There, veterinary surgeons transfer the embryos from the rabbits into the wombs of cows.

Genetic engineers work on producing superior animals and plants by taking genetic material from the cells of one strain or species, and adding it to the growing cell-material of a different type.

In animals, donor material has to be introduced into a female egg. With plants, however, it is much simpler. In the right conditions, any single plant cell can be manipulated to produce a whole plant. Agriculturalists can clone plants, producing hundreds or even thousands of new plants, which are genetically identical, all from the same piece of material.

Cloning plants

First, the scientist removes cell material, then he grows it in a rich mixture of hormones and nutrients. The cells divide and redivide, producing a mass of plant material called a *callus*. The *callus* will keep growing while the scientist cuts it up repeatedly. Each division, with the proper care, turns into an embryo plant.

All the embryo plants are identical clones of the original plant, all containing identical genes, all programmed to do the same thing at the same time. In identical conditions, the cloned plants will all grow at the same speed, have the same number of leaves and flowers, and all flower and fruit almost simultaneously. This enables oil-palm farmers, for example, to harvest all the palm nuts at the same time, instead of waiting while some ripen.

Cloning raises questions about the limits to which man should go in his attempts to improve on nature or play at God. Researchers have succeeded in cloning both frogs

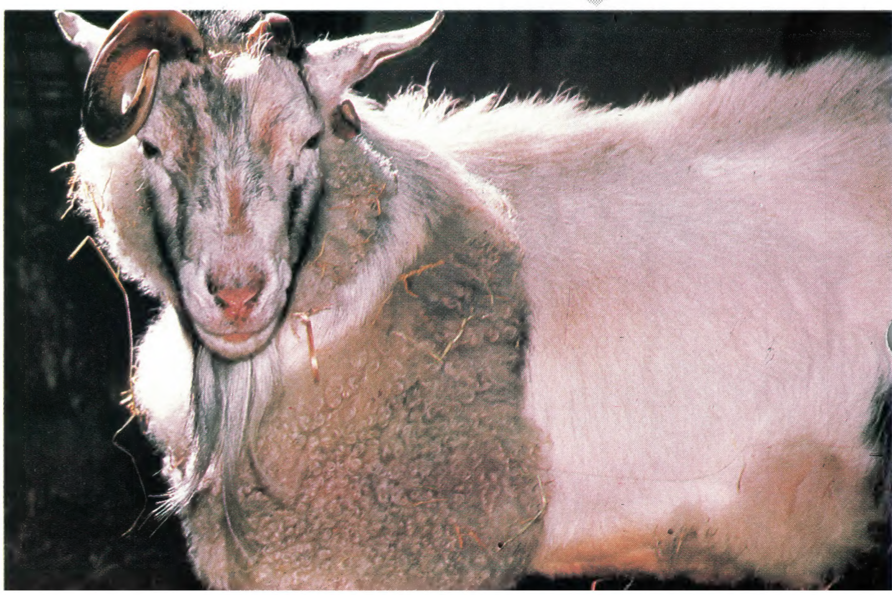
Just amazing!

LIFE EVERLASTING

DRACULA MAY LIVE IN FICTION. BUT IF CRYOGENICS AND CLONING WERE COMBINED, DEEP FROZEN CELLS FROM OUR BODIES COULD BE USED TO CLONE OURSELVES – LONG AFTER DEATH.

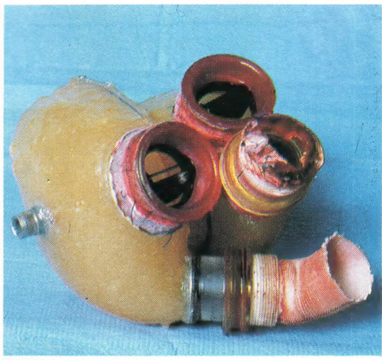
Paul Raymonde

A 'geep' by any name *is a pathetic misfit. This specimen, created from the cells of an embryo sheep and goat, raises serious ethical questions about creating life in the laboratory.*



Topham

Hank Morgan/SPL



Rex Features

***Surgeons replace** a damaged heart with the Jarvik-7 – the most commonly used artificial heart. It costs about a million dollars. The 'Phoenix' heart (above), devised by an American dentist, is cheaper, but has not been officially approved.*

and mice in the laboratory, taking away the nucleus of the mother's egg, and replacing it with the nucleus from a cell of donor tissue. Human experimentation has been carried out to a limited extent, but in many countries there are strict rules for research laboratories, which prevent experiments on human embryos created outside the body continuing after a certain number of days. The science fiction vision of a world full of identical 'worker clones', slaving away in factories, is never likely to arise.

RECYCLING ELEPHANTS

Mammoths found preserved in ice in Siberia are known to be at least 10,000 years old. Tribesmen there have even fed the flesh to their dogs as thaws and floods uncovered the huge, extinct creatures. It is possible that cell tissue, if recovered while still frozen, could be revived. If the nucleus was extracted from these mammoth cells and used to replace the nucleus of a cow elephant's fertilized egg, it may be possible to create a mammoth clone born of the elephant in the usual way. An extinct species, thus, could once again be re-established on Earth for the first time.

Novosti

Man's obsession with overcoming death has led some people to put their faith in cryobiology – the freezing of a body as soon as it has died – in the hope that at some future date it can be revived and made well again. A number of people have had their corpses frozen and sealed in deep-freeze caskets, waiting to be brought back to life at some future date.

Scientists have already succeeded in reviving bacteria found frozen for thousands of years in ancient ice-fields. Soviet scientists also claim to have discovered revivable cells in the bodies of woolly mammoths discovered preserved in ice and permafrost.

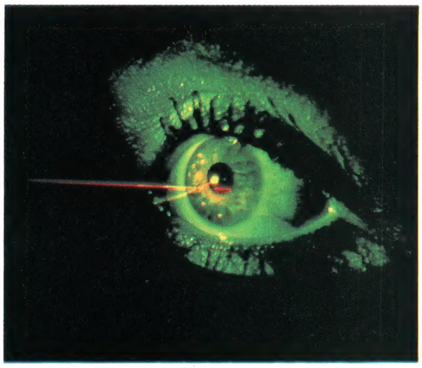
The surgeon's role

Replacement surgery is one of the major medical achievements of the second half of the twentieth century. Aging arthritic hips can be replaced with new hips of steel and plastic. Blindness due to cataracts can now be reversed by replacing the clouded eye-lens with a new one made of acrylic.

Deteriorating arteries can be removed, and replaced with efficient new ones of polyurethane. Hearts and kidneys, too, can be replaced with artificial versions. In some cases, the body rejects the new item, or refuses to 'work' with it. New materials are being created as close as possible to the body's own materials. Some bone replacements incorporate synthetic versions of bone material, which eventually become completely accepted by the body with living tissue growing on to the artificial bone.

With transplant surgery, living tissue and human body parts are used to replace damaged ones. To overcome the body's natural reaction to reject the new part, transplant patients have to take anti-rejection drugs, and a major problem is that the drugs suppress a large part of the immune system, making them prone to infection.

Genetically-engineered monoclonal antibodies are living cell forms that are programmed to attack only certain cells in the body. Success with these will mean that the human body may be serviced as easily as the family car – with worn-out parts being taken out and new parts fitted from the shelf.



Alexander Tsiaras/SPL

***Lasers have revolutionized** eye surgery, which requires extreme precision. The YAG laser mounted on an optical fibre is used in operations to replace lenses.*

SPARE PARTS

Synthetic replacements are now used from head to toe to repair the human body. They include:

Skull plates, made from metal alloy, and used after brain surgery
Glass eyes, made of glass or plastic, to replace diseased or injured eyes
Bone implants, made of plastic or metal alloy, to replace missing bones or repair bone defects
Oesophageal tube, made of plastic, to bypass narrowing in the gullet
Heart valves, made of plastic or metal alloy, to replace diseased ones
Pacemaker, consisting of an electronic box powered by batteries, to regularize the heart after a heart attack
Breast implants, made of silicon gel, to increase size or replace the original after removal
Tendon implants, made of carbon fibre, to replace damaged tendons and ligaments
Knee joints, made of metal alloy to replace broken or arthritic knees
Finger joints, made of flexible rubber, to replace arthritic joints

CNRI/SPL

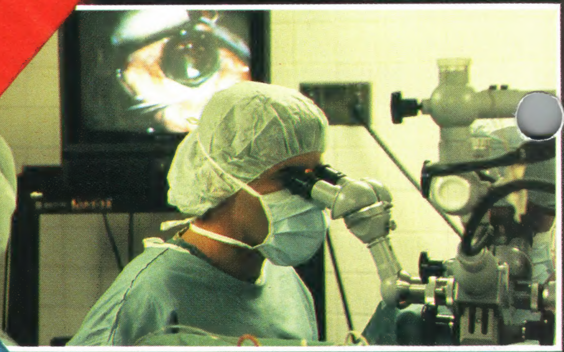
The hip-bone is connected to the thigh bone by a steel ball joint. The artificial part shows yellow against the green of the real bone in this false colour picture.

Alexander Tsiaras/SPL

The power of the surgeon to mend the body by replacing defective parts with artificial substitutes has been greatly enhanced by the use of lasers.

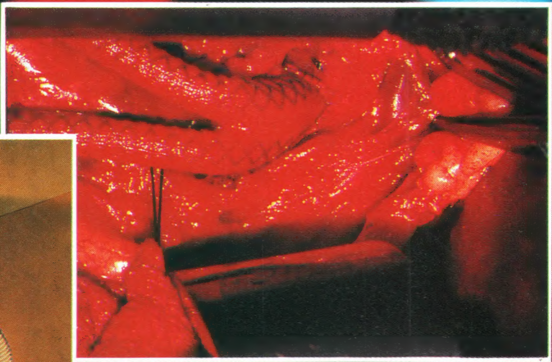
J.M. Nossant/Gamma/Frank Spooner Pictures

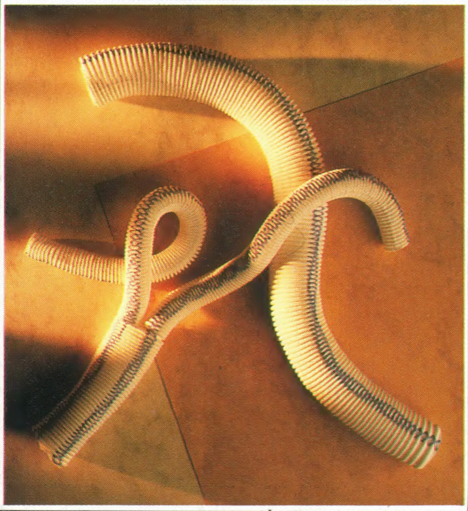
Reaching the parts other artificial hands have not reached, this French version grasps with precision and has great dexterity. It is activated by the forearm muscles without any other power source.



Georgia Lowell/SPL

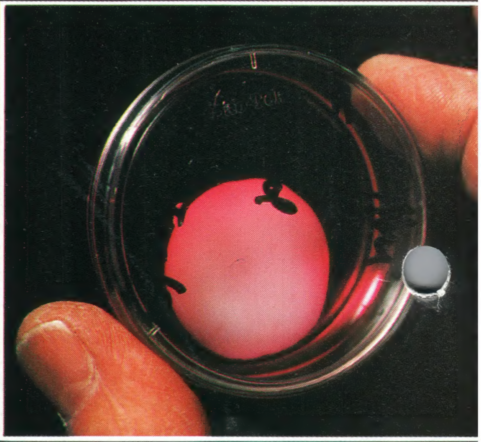
Cataract removal is one of the most commonly performed eye operations. It involves removing the clouded lens and, often, substituting a plastic implant. Here, the operation is filmed on video and simultaneously relayed to a lay audience to explain the procedure.





Design Council/Vascutek

Knitted tubes replace diseased arteries. The smooth inside lets the blood through freely, while the hairy outside helps new tissue to grow over it.(above).



Hank Morgan/SPL

Synthetic skin is grown in a culture dish by combining collagen and fibrous tissues. It is used for badly-burnt patients who have not enough of their own skin left for grafting.